SEVENTEENTH ANNUAL REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY

TO THE

SECRETARY OF THE INTERIOR

1895–96

CHARLES D. WALCOTT

DIRECTOR

IN THREE PARTS

PART I.—DIRECTOR'S REPORT AND OTHER PAPERS.

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Department of the Interior,
United States Geological Survey,
Washington, D. C., July 22, 1896.

Sir: I have the honor to transmit herewith the report of the operations of the United States Geological Survey for the year ending June 30, 1896.

In this connection permit me to thank you for the continued interest you have manifested in the work of the Survey.

I am, with respect, your obedient servant,

Chas. D. Walcott,

Director.

Hon. Hoke Smith,
Secretary of the Interior.

SEVENTEENTH ANNUAL REPORT OF THE UNITED STATES GEOLOGICAL SURVEY.

CHARLES D. WALCOTT, DIRECTOR.

INTRODUCTION.

During the fiscal year 1895–96 the organization of the Geological Survey as set forth in the Director's last report was continued without material change, and the field work of 1895 was largely a continuation of that of the previous season.

The most important change made within the year affecting the work of the Survey was the enactment by Congress of legislation providing for the monumenting of the topographic surveys. The provision is embodied in the sundry civil appropriation act approved June 11, 1896, and is in the following words:

> *Provided,* That hereafter in such surveys west of the ninety-fifth meridian elevations above a base level located in each area under survey shall be determined and marked on the ground by iron or stone posts or permanent bench marks, at least two such posts or bench marks to be established in each township or equivalent area, except in the forest-clad and mountain areas, where at least one shall be established, and these shall be placed, whenever practicable, near the township corners of the public-land surveys; and in the areas east of the ninety-fifth meridian at least one such post or bench mark shall be similarly established in each area equivalent to the area of a township of the public-laud surveys.

The enactment above quoted does not provide for the protection of the monuments thus to be erected from removal or defacement, but such legislation was incorporated in the Indian appropriation act approved June 10, 1896, in which occurs the following clause:

> *Provided further,* That hereafter it shall be unlawful for any person to destroy, deface, change, or remove to another place any section corner, quarter-section corner, or meander post, on any Government line of survey, or to cut down any witness tree

or any tree blazed to mark the line of a Government survey, or to deface, change, or remove any monument or bench mark of any Government survey; that any person who shall offend against any of the provisions of this paragraph shall be deemed guilty of a misdemeanor and, upon conviction thereof in any court, shall be fined not exceeding two hundred and fifty dollars, or be imprisoned not more than one hundred days. * * *

Under the provision for establishing the monuments and bench marks, a base monument, connected with sea level whenever practicable, will be established at some point in each area under survey, and the elevation of all the monuments and bench marks in that area will be referred to the base-level monument. In a communication to the honorable the Secretary of the Interior, proposing this legislation, the Director made the following statement:

It is my opinion that the maps of the Survey would be enhanced in value fully 100 per cent if permanent records were left on the ground, in the form of monuments, to show the position of triangulation points and township corners, and their true elevation above sea level or some fixed point. Under existing law there is no authority for establishing such monuments. If the amendment proposed is substituted for the clause in the estimates, the Survey will be in position to establish the monuments as proposed, and thus connect the topographic surveys with the land surveys and with the surface of the country. This will give the surveys greater usefulness in engineering work of every kind, for the utility and practical value of any survey is largely dependent upon the measures taken to preserve its results and to render possible the ready identification and practical use of these results.

To accomplish this monuments are indispensable, and from the experience already gained in the field, it is well known that if township corners and land surveys are to be preserved there must be established near them permanent monuments whose positions are marked on the maps. It is an indisputable fact that the practical utility of the surveys in much of the region west of the ninety-seventh meridian, in connection with mining, irrigation, water supply, and to a certain extent in the matter of railroad location, depends upon the practicability of identifying the results of the survey on the ground. In many areas the present system of surveying will suffice for the purposes of the geologic map, but for the uses mentioned above, and for work in the coal and iron areas of the Appalachians, the Lake Superior, and similar regions, the approximate location of contours will not suffice. Certain points must be capable of identification by means of monuments or bench marks, and this identification, to be of value, must be absolute.

It should be remembered that all industrial enterprises in the public land States are based upon public-land surveys, and hence the topographic surveys, to be of the greatest practical value, must be connected and identified with those land surveys. It should also be borne in mind that the addition of permanent monuments connected with the public-land surveys will aid in preserving and identifying the latter. This is especially true of the western portion of the country, where lack of population will prevent private development from perpetuating the monuments which are now used to mark the public-land surveys. Many of these marks are made of material that is subject to rapid decay; others are so insecurely fixed that within the next fifty years all of those outside of cultivated lands or the limits of mining districts will have disappeared. The establishment of a few conspicuous monuments of durable material will be of great value as a basis for the resurvey of the public lands, should this ever become necessary. It is not proposed to locate the monuments in place of the township monuments, but to put them a few feet away from the township monuments, and record in the field notes their relation to the latter. It is not the intention to provide for the reestablishment of land office lines or corners, but to mark such lines or corners whenever it is practicable to do so, as stated above.

The cost of doing this and of running more accurate lines of levels than it has been the practice in the past to run, will be small as compared with the benefits that will accrue therefrom.

The original object of the topographic map was to serve as a basis for the geologic map of the United States, but with the progress of the Survey from year to year the public have become more and more acquainted with the maps, and a strong demand has grown up for the topographic maps as such, and I now think it is time the topographic surveys should be connected directly with the land surveys in the manner proposed, and that permanent monuments should be left in all portions of the country where the surveys are made.

Of the benefit the establishment of the proposed monuments will be to the geologists of the Survey, to mining interests, and to all engineers engaged in irrigation work, I beg to submit the following statement:

AREAL GEOLOGY.

In areal geology the geologist endeavors to delineate upon his map as accurate a picture as possible of the outlines or boundaries of different rock formations as they occur on the tract of ground which the map represents, in order that from this areal map he may draw deductions as to the underground structure of that and adjoining regions, and construct profiles showing the courses and positions at various depths of these different rock formations and of their contained useful minerals, such as coal, iron ore, salt, etc.

Topographic maps, even when the result of the most improved methods and greatest skill, are necessarily more or less imperfect representations of the earth's surface, and the geologist often finds it difficult to determine the exact location upon his map of an important geological feature. In the mountain regions the sharp summits of hills or mountains have been used by the topographers as triangulation points, and (thus located with greater accuracy than other points) may be used by the geologist to locate a given point if a monument has been built. Less accurate locations may be obtained from intersections of streams, valleys, and ridges, or of artificial features, such as roads, buildings, etc. In the mountain regions there are likely to be considerable areas where such features are entirely wanting or are not available. Often triangulation monuments built of loose stones are scattered about, and afterward others may be built so that they can not be distinguished from those built by the topographers of the Survey. It thus becomes apparent that it will be of great use to the geologist in mountain regions to have permanent and accurately located monuments within short distances of each other, to which he can refer in locating important geologic features and in checking on the ground the accuracy of his geological work. On the Great Plains area such monuments are even of greater importance. Elevated points that would serve as triangulation points are generally wanting; intersections of important streams are not often at hand; and there are few natural features capable of representation on the map to which he can tie his observations. His only recourse is to township or section corners, when they can be found. Under the present system of marking such corners, however, the stakes or stones have often been destroyed or moved, and they have an unknown error of location, as they are not connected with any system of triangulation or exact measurement.

In the rolling and hilly areas west of the Mississippi, and the mountain areas of the Appalachian region and New England, the need of exact datum points is fully as great as in the West. This is particularly true in the survey of the great mining areas of the Lake Superior region, and the great coal fields of the Mississippi Basin and the Appalachian system. This will be spoken of more especially under the following heading:

MINING GEOLOGY.

In mining geology, the same advantages will accrue as in areal geology, but to a greater degree. A large part of the observations of the mining geologist are made under ground, and their location is referred to a single point on the surface. This necessitates a still higher degree of accuracy for the location of such points as mouths of shafts or tunnels, because any considerable error may entirely vitiate the deductions drawn as to the probable location under ground of ore bodies. Such points are located by mining surveyors with reference to corners of claims, and these in their turn with reference to some township corner. If the township corners are accurately indicated on the ground and on the map with reference to other topographical features, the other locations can be made in the office from the given starting points. In present practice, inasmuch as it is known that township corners may have a considerable though unknown error (in some cases of several hundred feet, and in one known case of nearly a quarter of a mile), it is found to be necessary to make a new survey to determine the location of such mine openings as serve to connect underground workings with the surface. Owing to this, it is often the practice at present among local mining surveyors to connect their surveys with the triangulation points of the Government geological surveys, because they are more accurately and permanently located than land-survey marks. At the present time, however, these monuments are built of piles of stone, and often, when stones are scarce, of a single stone with a bottle buried beneath it, containing a record of the position of the monument; and again, the points are more or less widely separated, as they are made with reference only to the triangulation.

The vertical element, or the exact level, is of the greatest importance in coal fields where the rocks are approximately horizontal, for upon a correct determination of the vertical element depend all of the geologist's stratigraphical and structural results. Within most of the Appalachian coal field the dip is less than 2 degrees, or 200 feet to the mile Now, the geologist must build up his stratigraphical columns and his structure of the region upon the topographic map which he uses. It is a delicate operation, and it is evident that a slight variation in the elevation used as a base will result in a very great change of structure. It is found in practice that while the coal beds appear to slope regularly from the margin of the basin toward the center, this apparently simple structure is complicated to a remarkable extent by slight but very irregular undulations, which traverse the field in every direction. If the errors of structure affected only the value of the scientific results they would be serious enough, but when, sooner or later, the mining engineer endeavors to make use of the maps, he is liable to be misled by them. It has been the practice of the geologist to run levels and check errors in every possible way, but if he had monuments to refer to, the elevations of which were already determined, he would have a constant check upon his work.

In the Lake Superior region the monuments and bench marks will give a basis for accurate maps which is necessary in connection with the development of the great mining operations there, both the exploitation of the mines and the extension of railroads and the building of graded roads. These would also be of great service to the timber interests, in the establishment of winter roads, and of special narrow-gauge railroads, which are so necessary to carry the timber to the main railroad lines. I think that a standard upon which surveys shall be based will be of inestimable value to all mining regions.

The Division of Hydrography of this Survey is conducting its operations under the appropriation "for gauging the streams and determining the water supply of the United States, including the investigation of underground currents and artesian wells in arid and semiarid sections" Its work is widely distributed. Streams in various parts of the United States are measured, and the underground conditions affecting water supply are studied in portions of the Great Plains region from the Dakotas to Texas. The results of this work have application in questions of water supply for irrigation and for power, and although the investigations relate primarily to quantities of water, yet there are constantly arising questions of the utilization of this water, such questions being dependent for their solution upon facts of relative elevation. That is to say, in any consideration of water resources the engineer has to ascertain first the quantities available and next the relative elevation of these quantities with respect to the point where the water is to be used, either for irrigation or for power. The one fact is as necessary as the other, for without "head," or difference of elevation, water is to a large extent useless.

The profitable employment of the water resources, whether from streams or wells, is determined often by very small differences in elevation. A few inches per mile of rise or fall may make or mar a project involving the reclamation of large areas, or may be the determining point in the location of a power plant. Thus it results that no sooner is the public informed as to matters of water quantity than an urgent appeal is made for exact information concerning slopes and elevations.

The relative elevations of land and water, and of different bodies or streams of water, are shown in a broad way on the present topographic maps; but the information is not sufficiently accurate or detailed, especially where matters of practical application depend upon differences in elevation of a few feet, or even inches. The value of the topographic maps, as far as the utilization of the water resources is concerned, would be increased many-fold if, along the principal streams and the broad, nearly level valleys, accurate level lines were run and occasional monuments or bench marks were located at distances of 5 or 6 miles, these being shown upon the map. Then when a question as to diverting water from a stream or from wells on the low land is brought up, it will be possible for any person of fair intelligence to take these maps and determine in a general way, from inspection, the feasibility of the project, or to go upon the ground and settle at small outlay of time and money any doubt as to the difference of elevation.

In this way many projects which are impossible would at the outset be condemned, and on the other hand attention would be drawn to feasible schemes for the development of the natural resources of the country. As the matter now stands, an engineer, having determined upon the water supply and noted the general location upon the present topographic maps, must rerun many of the lines if he would know the exact elevation of any point. Many thousands of dollars expended in such work could be saved by the simple provision of placing a few permanent marks at the time the topographic surveys and the precise level lines are being run.

In addition to granting authority for monumenting the topographic surveys, Congress made provision at its last session, by joint resolution approved February 28, 1896, for continuing the distribution of the publications of the Survey to two libraries in each Congressional district and four in each State at large, in extension of the distribution previously provided for. Under authority of this provision and of the statutes previously enacted and in force, all the publications of the Survey except the annual reports are now distributed to four libraries in each Congressional district and eight libraries in each State at large. The annual reports are distributed by Senators and Representatives direct, as public documents are usually distributed. The character of these reports is such that it seems highly desirable that all libraries which receive the other publications of the Survey should receive the annual reports also. This, however, can not be brought about except by Congressional action.

The operation of the Civil Service rules as affecting appointment, retention, and advancement in the Survey has been highly satisfactory during the year and productive of good results. By Executive order of July 15, 1895, the positions of geologist, paleontologist, chemist, engraver, and all other places the duties of which are of a scientific or technical character, and which had previously been exempt, were made subject to competitive examination. The effect of this order, taken in connection with previous orders and with the general revision and extension of the rules made and promulgated by the President May 6, 1896, whereby the positions of chief clerk, chief disbursing clerk, disbursing clerk, and confidential clerk were likewise made subject to examination, was to render subject to competitive examination all positions in the Survey of every grade and class except the place of laborer.

In July, 1895, a conference was held between the Director and a number of the members of the staff in reference to the revision of the explanatory text which is printed on the inside of the cover of each folio of the Geologic Atlas of the United States. It was deemed wise to make such a revision, because important advances in petrography and in general geologic nomenclature had been made since the text was written. The members of the Survey who took part in the conference and the revision were Messrs. T. C. Chamberlin, S. F. Emmons, C. R. Van Hise, Arnold Hague, G. K. Gilbert, Henry Gannett, and Bailey Willis. The changes that were made may be observed by a comparison of the explanatory text of folio No. 20 with that of folio No. 21.

At the time of the resignation of Maj. J. W. Powell from the directorship, in 1894, none of the folios had been published, though several were under way and the descriptive text therefor had been prepared. The first folio was issued after the present Director took charge of the Survey, but the name of Major Powell was placed upon the title page of the first 20 folios in recognition of the long-continued and important preliminary work which had rendered the publication of the folios possible.

In this connection mention should be made of the services rendered by Messrs. G. K. Gilbert and Bailey Willis in the development of the scheme of colors and conventional signs used in the folios, and by Mr. S. J. Kübel, chief engraver, in carrying the details of that plan into practical effect and producing by extended experimentation results of such mechanical and artistic excellence.

The Smithsonian Institution, National Museum, Coast and Geodetic Survey, General Land Office, and Government Printing Office have, as in previous years, cordially cooperated with the Survey in the endeavor to advance and perfect its work, and the members of the Survey have rendered diligent and faithful service.

PLAN OF OPERATIONS FOR THE YEAR.

In accordance with custom, a general plan of operations for the fiscal year 1895–96 was laid before the honorable the Secretary of the Interior on May 22, 1895, and was approved by him on June 8, 1895.

The detailed plan of work as approved by the Secretary, and in conformity with which the greater portion of the work hereinafter reviewed was executed, is on file in the Department. A general statement of appropriations and of allotments for work in geology, paleontology, and topography immediately follows, and where each party worked and what each party and office division accomplished will be found stated further on under the head "Organization and work of the year."

APPROPRIATIONS AND ALLOTMENTS.

SUMMARY OF APPROPRIATIONS.

For the fiscal year 1895–96 there was appropriated for the work of the Geological Survey the sum of $521,890. Separate amounts were, by the terms of the several acts, set apart for specific branches of work and for the salaries of persons connected with those branches. For convenience of reference these separate appropriations are here brought together and classified, as follows:

For pay of skilled laborers, etc		$13,000
For topographic surveys	$150,000	
For pay of two geographers and two topographers	9,200	
Total		159,200
For geologic surveys	100,000	
For investigations in Alaska	5,000	
For pay of four geologists	13,700	
Total		118,700
For paleontologic researches	10,000	
For pay of two paleontologists	4,000	
Total		14,000
For chemical and physical researches	8,500	
For pay of one chemist	3,000	
Total		11,500
For gauging streams, etc		24,500
For preparation of illustrations		13,000
For preparation of report on mineral resources		18,000
For purchase of books and distribution of documents		2,000
For engraving and printing maps		65,000
For rent		4,600
Total		443,500

Furthermore, there was appropriated in the same act for engraving, printing, and binding the publications of the Survey $37,000, this sum to be disbursed, not by the Survey, but by the Public Printer. The items are as follows:

For engraving illustrations for report of the Director	$7,000
For engraving illustrations for monographs and bulletins	10,000
For printing and binding monographs and bulletins	20,000
Total	37,000

Lastly, the legislative, executive, and judicial act appropriated for the Survey $41,390, in two items, as follows:

For salaries of Director, chief clerk, chief disbursing clerk, librarian, and photographer, together with clerks, messengers, et al., to the number of twenty-nine persons in all	$31,390
For rent	10,000
Total	41,390

Thus the aggregate appropriation for the Geological Survey for the fiscal year 1895–96 was $521,890.

ALLOTMENTS TO GEOLOGIC WORK.

As stated above, the total appropriation for geologic work for 1895–96, including the special appropriation for work in Alaska, was $118,700.

The following table exhibits the allotments that were made to the heads of the several geologic parties:

Party.	Allotment.
Executive office	$9,000
Shaler, N. S	3,500
Emerson, B. K	750
Dale, T. Nelson	2,800
Hobbs, W. H	500
Wolff, J. E	750
White, C. David	2,200
Taff, J. A	3,600
Campbell, M. R	4,000
Hayes, C. W	4,500
Keith, A	3,000
Darton, N. H	3,000
Clark, W. B	600
Eldridge, G. H	3,700
Van Hise, C. R	8,000
Chamberlin, T. C	3,000
Gilbert, G. K	6,500
Hill, R. T	6,000
Weed, W. H	2,500
Emmons, S. F	7,000
Hills, R. C	1,000
Cross, C. W	6,000
Hague, A	4,500

Party.	Allotment.
Diller, J. S	$5,800
Turner, H. W	4,000
Lindgren, W	3,500
Lawson, A. C	500
Willis, Bailey	8,000
Becker, G. F	9,000
Contingent fund	1,500
Total	118,700

ALLOTMENTS TO PALEONTOLOGIC WORK.

The total appropriation for paleontologic work was $14,000. It was allotted to the several branches as follows:

Section.	Allotment.
Paleozoic work	$1,500
Mesozoic work	2,000
Cenozoic work	2,300
Paleobotanic work	4,600
Vertebrate paleontologic work	2,000
General assistant's salary	1,200
Contingent fund	400
Total	14,000

ALLOTMENTS TO TOPOGRAPHIC WORK.

The sum appropriated under the head of topographic surveys was $150,000. Of this amount the statute specifically provided that $35,000 should be expended in the region west of the ninety-seventh meridian, in the States of North Dakota, South Dakota, Nebraska, Kansas, Texas, and the Territory of Oklahoma, and at least one-third of the remainder west of the one hundred and third meridian The following allotments were in accordance with these provisions. These allotments include certain stated salaries which were specifically provided for and which aggregate in amount $9,200, making the total appropriation for topography $159,200.

Section.	Allotment.
Administration	$6,200
Atlantic section	45,000
Central section	30,000
Rocky Mountain section	30,000
Pacific section	30,000
Contingent fund	18,000
Total, including stated salaries	159,200

ORGANIZATION AND WORK OF THE YEAR.

The general organization of the Survey, by branches and divisions, remained the same as during the previous year.

The approved plan of operations was executed in all essential particulars, such slight departures therefrom as were made being due to conditions arising during the year which could not be anticipated. Following is a detailed account of the work:

GEOLOGIC BRANCH.

DIVISION OF GEOLOGY.

The geologic field work was carried on by twenty-eight parties, each with a geologist or an assistant geologist at its head, the heads of parties reporting immediately to the Director. For convenience of administration and reference, the field of operations is divided into six grand divisions or regions, as follows: The New England region, the Appalachian region, the Atlantic Coastal Plain region, the Interior or Mississippi region, the Rocky Mountain region, and the Pacific region.

As during the previous year, the work of the year 1895–96 was in the main areal geologic surveying, the distribution and relations of the various rock formations being delineated upon the topographic base maps. Considerable attention was directed, however, to special investigation, including a reconnaissance of the gold and coal resources of Alaska.

NEW ENGLAND REGION.

This region includes the New England States and the eastern portion of New York. In it four parties were engaged, as follows:

Shaler party.—During the field season of 1895, Prof. N. S. Shaler completed the survey of the Narragansett coal field of Rhode Island and an adjoining area in Massachusetts. The work done in this and previous years has now been brought to a condition of preparation for publication, and an approximate determination of the geologic conditions presented by an area of singular difficulty has been attained. The economic results of this work include a knowledge of the probable distribution of the coal deposits and the value of the same, and determinations relating to clays, building stones, soils, etc.

In the office, Professor Shaler's time was given chiefly to the completion of the memoir on the geology of the Narragansett coal basin. In this work he was assisted by Mr. J. B. Woodworth and, to some extent, by Mr. A. F. Foerste. Attention was also given to the preparation and completion of a report on the Glacial brick clays of Rhode Island and southeastern Massachusetts, which appears in this volume. This memoir also includes observations on the Tertiary and Cretaceous clays, and on the evidence concerning the subdivisions of the Glacial period in the New England section of the continent. It is based largely upon observations made by Mr. Woodworth and Mr. C. F. Marbut. Inquiries touching the methods of study and experimentation in road-building materials, in this country and abroad, were continued at intervals during the year.

Emerson party.—In continuation of the mapping of the areal geology of central Massachusetts, Prof. B. K. Emerson mapped 95 square miles of the northern half of the Barre sheet and 25 square miles of the southern half of the Bear Mountain region, on the Pittsfield and Sheffield sheets. A resurvey was made of the Becket sheet, the northern half of the Sandisfield sheet, the southern half of the Barre sheet, the northern part of the Marlboro sheet, and a region lying south of the Marlboro sheet; in all, 505 square miles of resurvey. The work on the Becket and Sandisfield sheets is practically completed, and that on the Barre and Brookfield sheets is nearly done. Work on the Worcester, Blackstone, Marlboro, and Webster sheets has been well advanced; preliminary maps have been colored, and it is expected that the sheets will be finished next season. In addition to the detailed surveys above described, a reconnaissance was extended by Professor Emerson over the Winchendon, Fitchburg, and Groton sheets.

The field work of the season, taken in connection with that previously done, has resulted in the determination of the limits of the stratigraphy of the pre-Cambrian areas across Massachusetts south of the Hoosac area, the mapping of the crystalline rocks across to the Boston Basin, and the study of the pre-Cambrian and Cambrian conglomerates on the Rhode Island border. The last-named work was executed by Professor Emerson's assistant, Mr. Joseph H. Perry.

The principal economic results of the season were the determination of the origin and distribution of the Becket gneiss, which is a fine building stone, and the study of the verd-antiques of Westfield and of the soapstone and kaolin deposits of Blandford.

In the office Professor Emerson was engaged mainly in the preparation for the press of a monograph on the geology of the three river counties of Massachusetts. He also arranged and studied, with Mr. Perry's help, the rocks collected in the course of their joint work in Worcester County, and thin sections of the same.

Dale party.—In eastern New York and western Vermont, Prof. T. Nelson Dale, assisted by Mr. L. M. Prindle, Mr. F. H. Moffit, and, for a short time, Miss F. Bascom, continued the mapping of the areal geology of the roofing-slate belt and the study of the structural relations of the different beds of slate. The areal work included the mapping of 21 square miles, of which 4 square miles were resurveys. The work embraced portions of the Hoosac, Cambridge, Fort Ann, Pawlet, and Whitehall sheets. Professor Dale also made a reconnaissance of 8 square miles on the Poultney sheet, in Vermont, and upward of 1,800 localities were examined and notes made upon them in the field note-books.

The principal economic result is a collection of data for a bulletin on the roofing-slate belt of eastern New York and western Vermont. This work will show the areal distribution and structural relations of the red and green slate belts, and the location of the more important quarries. Professor Dale expects to elucidate the geologic principles pertaining to the slate region, illustrating the structural relations by diagrams and the chemical nature of the slate by analyses. This should be the means of introducing more rational methods of prospecting for and developing the slate quarries, and thus aid the slate industry.

In the office Professor Dale's time was given largely to the study and elaboration of the field notes and material collected during the field season, chiefly with a view to the preparation of the bulletin on the roofing-slate belt above mentioned.

Hobbs party.—Prof. W. H. Hobbs was engaged in the completion of the survey of the areal geology of the Cornwall sheet of Massachusetts. This work was begun when Professor Hobbs was connected with the New England division of geology, under Professor Pumpelly. When that division was abolished, at the time of the reorganization of the geologic branch of the Survey, in 1892, most of the field work was discontinued and several sheets were left unfinished. During the past summer Professor Hobbs surveyed 93 square miles and resurveyed 20 square miles, in a region where the structural geology is exceedingly complex. In addition a reconnaissance was made of 49 square miles.

The most important scientific result was the determination of the igneous origin of much of the acid granite and gneiss of the southern portion of the Cornwall sheet. The field work also confirmed the previous determination of the succession of the rocks occupying the Hoosatonic Valley proper.

In the office Professor Hobbs was employed during the brief period that he gave to the work of the Survey in the preparation of a preliminary report on the Sheffield sheet of the Geologic Atlas.

By special agreement Dr. F. J. H. Merrill, Director of the New York State Museum of Natural History, completed in southeastern New York the areal mapping of the Paleozoic and pre-Paleozoic formations of the areas lying between meridians 73° 45′ and 74° and parallels 40° 30′ and 41°, and during the winter his field notes were written up and a map of the area was prepared, which will be included in the proposed special New York City folio.

APPALACHIAN REGION.

This region embraces the mountain system and adjoining hills and plateaus that extend from the Hudson River on the north to central Alabama on the south. In it seven parties were engaged in field work, as follows:

Wolff party.—In continuation of the work of the field season of 1894, Prof. J. E. Wolff began the mapping of the Franklin sheet, in the Archean highlands of New Jersey. Almost all his time was given to the gneissic area of the eastern part of the sheet, of which 35 square miles were completed. This work shows the existence of large areas of eruptive granite along the western edge of that part of the highlands. The limestones and other sedimentary rocks of the western part of the Franklin sheet will be taken up another season.

During the winter Professor Wolff prepared maps and other data relating to the Lake Hopatcong geologic folio.

Keith party.—To Mr. Arthur Keith was assigned the mapping of the Frederick sheet, of Maryland, and the special study of the crystalline rocks in the vicinity of Washington and to the southwest, across Virginia and extending into North Carolina. In the mapping of the Frederick sheet 900 square miles were surveyed; of the Mount Vernon, 670 square miles. Of the Patapsco, 150 square miles were carefully surveyed and 300 square miles covered by reconnaissance. To complete the Roan Mountain sheet, of Tennessee and North Carolina, 100 square miles were surveyed.

The principal scientific result of the work in Maryland and Virginia was the subdivision of the pre-Cambrian crystalline rocks into twelve formations and the determination of their structure. Mr. Keith also found that the Juratriassic structure was extended into the adjoining crystalline rocks, and that it was possible to correlate the Blue Ridge crystallines with those of the Piedmont Plateau. The crystalline series of northern and middle Virginia were also correlated with those of North Carolina and Tennessee. The Middle Cambrian series of Virginia and those of Tennessee were correlated, and numerous cross-shear zones and base-level periods were recognized and traced in the crystalline rocks.

The principal economic results were the investigation of the mineral resources of the areas mapped in Maryland and Virginia, and the detailed mapping of the marble belts of Maryland and the slate, soapstone, sandstone, serpentine, and talc deposits of Maryland and Virginia.

In the office Mr. Keith was engaged in the preparation of the maps and text of the Washington, Briceville, and Wartburg folios, of special reports on the larger crystalline rock groups of the Appalachians, and on the various stages of Appalachian erosion, and also on the marble and iron deposits of Cherokee County, N. C. In addition, the proofs of the Loudon and Morristown folios, in course of preparation, were read and corrected.

Taff party.—In the coal fields of West Virginia, Mr. J. A. Taff, with the assistance of Mr. A. H. Brooks, mapped the entire Buckhannon sheet and a portion of the Sutton sheet, making a total area of 1,395 square miles, of which 1,313 square miles were included in the Coal Measures.

As regards the structural geology, Mr. Taff obtained scientific results that will have an important bearing upon the development of the coal resources of the area. Coal and limestone are the economic resources of the region. The lower series of Coal Measures contains six workable coal beds, and the upper series contains two. The stratigraphic and areal distribution of these beds was worked out with great care.

Mr. Taff had the assistance in the field of Mr. David White and Mr. George H. Girty, who collected and studied the fossil flora and fauna, respectively. Mr. Stose and Mr.

Ljungstedt, of the Editorial Division. also assisted in the field work for short periods.

In the office Mr. Taff began work on the Buckhannon folio, which includes maps, sections, and text. This folio was completed and submitted for publication before the close of the fiscal year. Data were also prepared in relation to the Sutton folio, and Mr. Taff prepared a structure map of the north Potomac coal basin, showing its deformation by contours at intervals of 100 feet.

Campbell party.—The party in charge of Mr. M. R. Campbell continued the survey of the coal fields of West Virginia to the southwest of the area surveyed by Mr. Taff. The field work was completed on two sheets, the Raleigh and the Kanawha Falls, 938 square miles of the former and 680 square miles of the latter being surveyed and mapped. The eastern half of the Charleston sheet was mapped also, as well as portions of the Oceana and Nicholas sheets. The total area covered during the season was 2,500 square miles. Of this, the work on the Oceana and Nicholas sheets was of the nature of detailed reconnaissance, to secure data to correlate the geology with the geology of the Raleigh and Kanawha Falls sheets, which, as stated, were thoroughly surveyed. Toward the close of the season, about 70 square miles of the coal fields of the Bristol sheet were surveyed, in order to adjust the geologic boundaries to the revised topographic map. Mr. Campbell was assisted in the work by Mr. W. C. Mendenhall and Mr. B. F. Phillips, the latter as a collector.

All of the scientific results of the season's work are not yet fully elaborated. One of the most important is the verification of Mr. David White's correlation in the Pottsville series along New River. Mr. White asserted a year ago that the Quinnemont and Fire Creek coals were one and the same. This view was fully borne out by the structural evidence obtained by Mr. Campbell and his assistants. Data were obtained regarding the changes which the Pottsville series undergoes in the middle of the Kanawha basin. They also connected their work with that of the previous season in the region of Tug Fork of the Big Sandy River. Some important results were also obtained in the study of the physiography of the region under survey.

It is anticipated that the publication of the Raleigh and Kanawha Falls folios will throw considerable light on the question of the productive and nonproductive coal areas. In addition to the well-known fields along the New and Kanawha rivers, several other areas of excellent coal seams were carefully mapped.

In the office Mr. Campbell first prepared the material for the Tazewell folio, and then work was begun on the large geologic section along the New and Kanawha rivers, the results of which are embodied in a paper that appears in Part II of this Annual Report.

White party.—As in the preceding year, Mr. David White was instructed at the beginning of the season of 1895 to cooperate with the geologists engaged in mapping the areal geology on the line of the Appalachian coal fields. In this manner he assisted Mr. Taff in the areal work on the Sutton and Buckhannon sheets, at the same time making extensive collections of fossils. Later on, in September, he was with Mr. Campbell in the Kanawha Falls area.

Mr. White's work was largely for the purpose of correlating the various coal horizons under survey by the geologists, and in this connection he did considerable work on the southwestern border of the Tennessee coal field, reexamining a number of published sections and making a detailed survey of several new sections. This work resulted in showing a new base in the Tennessee coal fields and the disappearance of the lower Pottsville beds on the west side. The probable synchrony of the Sewanee coal bed in Tennessee and the Sewell coal bed in West Virginia was reduced almost to certainty.

It is anticipated that the study of the fossils gathered during the season will enable Mr. White approximately to correlate some of the lower coals of eastern Tennessee with those of the Tug or New River region of West Virginia, and also to correlate the beds of the latter region with those of Coal River, and thus to fix the relation of the coals of that district. It is also anticipated that the material collected will furnish the data for the construction of a section, based on the fossils of the Kanawha River as far up as the Pittsburg coal. This will be of great importance for comparison with the material collected in the various horizons to the north, in the Sutton and Buckhannon areas. It is hoped, moreover, that it will serve as a basis for a number of correlations with the coal beds of western Maryland and southern Tennessee.

In the office Mr. White was engaged in the main, for several months, in the unpacking and preliminary examination of the 120 boxes of fossils collected in the course of the summer's work. The results of this examination were communicated to the geologists, Messrs. Campbell and Taff, that they might thereby be aided in making correlations and drawing geologic boundaries within the field of work wherein he had cooperated with them. In the latter part of the year he was engaged in rewriting the text of his report on the flora of the Lower Coal Measures of Missouri. This report, which will form the subject of a monograph, is now nearly completed.

Darton party.—During a portion of the season Mr. N. H. Darton was engaged in mapping the Franklin and Monterey sheets, of West Virginia. The Franklin sheet lies to the southeast of the coal field and directly north of the Staunton sheet, which has been completed and published as a geologic folio. It also adjoins the Piedmont sheet, which was surveyed by Mr. Darton, conjointly with Mr. Taff, during the previous season. The survey of the Franklin sheet bridges the gap between the Staunton and Piedmont areas and adds to our knowledge of the stratigraphic geology of central Appalachian Virginia. The work also resulted in defining the distribution of the Rockwood iron ores and associated limestones in Pendleton and Grant counties, W. Va., and the discovery of manganese near Franklin, which may be of economic importance in the future. The area of the Monterey sheet is situated directly west of that of the Staunton sheet, and reaches, in its northwest corner, the Appalachian coal field. Special attention was given to the study of the various iron-ore deposits included within the area of the sheet. In this work Mr. Darton was assisted by Mr. J. E. Macfarland.

Mr. Darton was also engaged in field work in the Atlantic Coastal Plain region, which will be mentioned under the proper heading, and in the Interior or Mississippi region, which will be described in connection with the work of that region.

In the office Mr. Darton was employed, in connection with the geology of the Appalachian region, in the preparation of the Franklin folio.

Hayes party.—In continuation of the mapping of the areal geology of the southern Appalachians, Mr. C. Willard Hayes, assisted by Messrs. H. B. Goodrich, R. E. Dodge, and, for a time, Mr. J. E. Macfarland, completed the Tallapoosa sheet, of Georgia-Alabama, by surveying 892 square miles and resurveying 100 square miles, and he surveyed the Anniston sheet, of Alabama, in its entirety—922 square miles. Forty-eight square miles of resurvey were executed on the Cartersville and Rome sheets, of Georgia, and 200 square miles were resurveyed on the Gadsden sheet, of Alabama. About 250 square miles of reconnaissance survey were executed on the Marietta sheet, of Georgia, and 660 square miles on the Columbia, Linden, and Waynesboro sheets, of Tennessee, the latter area embracing the most important portions of the Tennessee phosphate field.

The greater part of the season was devoted to the Tallapoosa and Anniston sheets, above mentioned, which are now ready for publication, so far as the field work is concerned. The resurveys in the Cartersville and Gadsden areas were to supplement and correct former work, and these sheets are likewise ready for publication. The reconnaissance work on the Marietta sheet was done for the purpose of establishing through that sheet the connection between the formations mapped on the Cartersville and the Tallapoosa sheets, which adjoin it on the north and west, respectively.

The work in the phospate region of central Tennessee was done for the most part in sufficient detail for final publication. The maps relating to the phosphate area will be complete areal geologic maps.

In the Georgia-Alabama metamorphic and crystalline region Dr. Hayes gave special attention to the mapping of the gold-bearing belts and the determination of their relations to adjacent formations. He found that the gold is almost invariably associated with basic eruptive rocks which are intrusive in mica-schist or gneiss. The extensive limonite deposits associated with sedimentary rocks were studied and mapped. By far the larger number of these deposits belong to one of three classes, each characterized by different associations. These are (1) deposits occurring at the top of the Knox dolomite and the base of the Chickamauga limestone, probably marking an unconformity and ancient land surface; (2) deposits occurring at the top of the Weisner quartzite, where that impermeable formation passes under the Beaver limestone, and which are probably due to favorable conditions for accumulation during the weathering of adjacent rocks; and (3) deposits occurring along fault lines, oftenest in the Weisner quartzite, but not confined to that formation, which also probably depend on favorable conditions for deposition during the weathering of adjacent formations, though they may have been formed at considerable depths, particularly where there has been much replacement of silica and lime by iron oxide.

In middle Tennessee, all available data were collected concerning the thickness and quality of the bedded phosphate and the extent of the nonbedded phosphate. This information will enable Dr. Hayes graphically to represent with a fair degree of accuracy the extent of the workable phosphate.

A number of points of scientific interest were developed during the field season, especially with reference to the stratigraphy of the Paleozoic formations of the southern Appalachian region. The succession in the Cambrian formations, and particularly the relations of the Weisner, Beaver, and Rome, are believed to be satisfactorily worked out. From the study of the phosphates and associated rocks of middle Tennessee some conclusions were reached regarding the physical conditions prevailing over a broad area in the southwestern Appalachian region during Silurian-Carboniferous time.

In the office Dr. Hayes platted his field notes and put them in shape for publication, so far as the condition of the topographic base maps would permit the completion of the platting of the areal geology. The finished manuscript of the Gadsden

(Ala.) folio was transmitted for publication and is now in press. A report on the Tennessee phosphates, published in Part II of this Annual Report, was prepared, embracing a large number of sections, together with maps on which the thickness of the phosphate beds is shown by a graphic method. A large map was also prepared for the Cotton States and International Exposition at Atlanta, which exhibited the work done by the Geological Survey in Alabama and Georgia.

ATLANTIC COASTAL PLAIN REGION.

This area embraces the Coastal Plain region extending from the mouth of the Hudson on the north to the Gulf of Mexico on the south. In it three parties were at work.

Clark party.—Prof. W. B. Clark, assisted by Messrs. R. M. Bagg and G. B. Shattuck, continued areal mapping in the northern portion of the Coastal Plain region, working on a number of sheets of central New Jersey. The Pemberton, Mount Holly, Hammonton, and Mullica sheets were nearly completed, while an area embracing the Lambertville, Princeton, Burlington, and Bordentown sheets was partly mapped, but not finished, as its areal geology was far more complex. To complete this area part of another field season will be required.

Of the area under survey during the field season of 1895, about 600 square miles required careful detailed work, while about as much more required comparatively little study.

The scientific results consist of a more accurate discrimination of the Cretaceous-Tertiary series of the northern Atlantic Coastal Plain. The economic results consist principally in a careful delimitation of the clays and marls.

In the office Professor Clark was engaged in laboratory work upon several topics connected with the geology and paleontology of the northern and middle Atlantic Coastal Plain, the results of which will be of service in the preparation of text and maps for geologic folios.

Darton party.—In connection with the preparation of a special map of New York and vicinity, Mr. N. H. Darton, in addition to the work mentioned on a previous page, resurveyed the Juratrias area of the Paterson, Staten Island, and Harlem sheets, comprising 337 square miles. He also made a reconnaissance of the Romney (W. Va.-Va.-Md.), the Woodstock (Va-W. Va.), and the Trenton (N. J.-Pa.) sheets.

In the office Mr. Darton gave considerable time to the preparation and proof reading of the Nomini (Md.-Va.) geologic folio, and considerable progress was made on the Washington and New York City folios. A special map was also prepared showing the distribution of the Potomac formation of Virginia, the District of Columbia, and a part of Maryland, to illustrate Prof. W. M. Fontaine's memoir on the Potomac formation in Virginia (Bulletin No. 145).

Shaler party.—Late in the season Prof. N. S. Shaler, assisted by Mr. J. B. Woodworth, began the survey of the Richmond (Va.) coal field. This work was interrupted during the winter and was taken up again in June, 1896.

Eldridge party.—Early in April work was resumed by Mr. George H. Eldridge upon the phosphate areas of Florida, with a view to completing the survey to determine the geology, extent, and value of the deposits. It is anticipated that this work will be finished in the late fall.

Three months in the office were devoted to writing out field notes and preparing the preliminary text and map relating to work already done in the phosphate areas under survey.

INTERIOR OR MISSISSIPPI REGION.

This region embraces the area lying within the British boundary on the north, the Gulf of Mexico on the south, the Rocky Mountains on the west, and the western slope of the Appalachians on the east. In it four parties were at work, as follows:

Van Hise party.—The areal work of the Lake Superior region, under the charge of Prof. C. R. Van Hise, was mainly in the Upper Peninsula of Michigan, though it extended a short distance into Wisconsin. It was confined between the meridians 87° 30′ and 89° and the parallels 46° and 46° 30′. The geologic work on the two atlas sheets lying between the meridians 88° and 89° and the parallels above mentioned was completed, and also the areal work to the Cambrian rocks on the third sheet to the east. This work involved the survey of 470 square miles, and in covering the area about 1,000 linear miles of traverse were made.

The principal scientific result of the areal work in the Upper Peninsula of Michigan was the outlining of three arms of Huronian rocks which project from the main area into the Archean. The chain of work between the Marquette and Menominee districts was also completed. The principal economic results were of a negative character. It was unknown whether east of the main area of Archean, between meridians 88° and 89° and parallels 46° and 46° 30′, there were Huronian troughs which might possibly produce iron ore. As stated above, such Huronian troughs have been outlined, but apparently none of them contain members so high as the iron-bearing formation, and therefore there is no promise that any of these newly outlined troughs will yield workable deposits of iron ore.

Professor Van Hise was assisted in his work by Messrs. J. Morgan Clements, W. N. Merriam, and H. L. Smyth.

In the office Professor Van Hise and Dr. Bayley were employed in part until February 1 in the final revision of the monograph upon the Marquette iron-bearing district. Professor Van Hise also gave part of his time to the final revision of an extended paper on the Principles of North American Pre-Cambrian Geology, which was published in Part I of the Sixteenth Annual Report of the Survey. Since February 1 he has been occupied with the proof reading of the last-mentioned paper and in the revision of Mr. C. W. Hall's bulletin upon the gabbro-schists and associated rocks of southwestern Minnesota, and of Mr.Clements's paper upon the Michigamme district, which latter was prepared by Mr. Clements after the close of the field season, Mr. Smyth collaborating with him and preparing the report on the eastern half of the district. It is anticipated that the joint report of Messrs. Clements and Smyth, with an introductory chapter by Professor Van Hise, will be made ready for publication during the fiscal year 1896–97.

Dr. Bayley was engaged the latter part of the year in the preparation of an abstract of the literature of the Menominee iron-bearing district and in describing some petrographic specimens for the Educational Series of Rocks.

Gilbert party.—The party in charge of Mr. G. K. Gilbert was engaged the greater part of the field season in work in Colorado and Kansas. It was largely reconnaissance, only about 25 square miles being surveyed in detail. The detailed work was on the Two Butte and Albany sheets of Colorado. In southeastern Colorado a reconnaissance was carried across the Catlin, Timpas, Las Animas, Higby, Lamar, Two Butte, Granada, and Albany sheets, and into parts of western Kansas immediately to the east of the two last-named sheets. The area embraces about 4,000 square miles.

Of the scientific results of this work the following may be said: It was previously known that in the vicinity of Pueblo and in the mapped districts lying immediately to the eastward the Cretaceous formations, while locally much flexed and folded, have a gentle descent northward. It was also known that they descended northward, with gentle dip, in Kansas. The work of the past summer shows that the same structure obtains through the eastern part of the Arkansas Valley in Colorado. It was also found that there are in that district many local flexures, and that these disturbances characterize the beds quite to the Kansas boundary. In the broadest valleys of the district the Cretaceous rocks are unconformably covered by gravels and sands of alluvial origin, spread during some part of Tertiary time by streams flowing eastward from the Rocky Mountains. These alluvial deposits correspond, at least in part, with a formation observed in Kansas and called "Tertiary grits."

A series of terraces flanking the Arkansas River and its terraces had been previously observed on the Pueblo and Nepesta areas. These were traced southward to the base of the mountains at Canyon and eastward for from 30 to 50 miles. It was ascertained that the terraces descend eastward, that they belong to the Arkansas Valley, and that they are newer than the high-level gravels correlated with the Tertiary grits.

In the northeastern part of the Two Butte sheet were found some bodies of volcanic rock of the character of laccolites. Lower Cretaceous and upper Juratrias beds are thereby arched upward in a dome 3 or 4 miles broad and a thousand feet high. These laccolites are exceptional in the character of their lava, which is more basic than any previously reported. The associated sedimentaries are hardened near the contact, and are thus rendered more resistant than the igneous rocks, with the result that the igneous rocks occupy the valleys and the sedimentaries the hills, an arrangement the reverse of that which obtains in the typical laccolitic localities of Utah and western Colorado.

The economic results of the work are as follows: The artesian water of the Arkansas basin is obtained from sandstones of the Dakota formation. These are overlain by shales, with some limestones, constituting the Benton, Niobrara, and Pierre groups. The Dakota sandstones are variable in thickness, quality, and arrangement, but the shale and limestone formations above them, which must be penetrated by the drill in order to reach the water-bearing layers, are remarkably uniform in character and thickness throughout the entire distance of the above-mentioned reconnaissance. It will therefore be possible, when the geology of the district has been mapped in detail, to indicate with considerable precision—say within 100 to 200 feet—the depth to which it would be necessary to drill at any point in order to reach the water-bearing rocks. Information of this character will be of great value to the residents of the Arkansas Valley. It will also be possible, after thorough geologic mapping, to indicate approximately the regions in which there is reason to believe that the water reached by the drill will rise to the surface.

The extensive gravel and sand deposits occupying the broader uplands of both sides of the Arkansas Valley constitute a reservoir in which a portion of the scant rainfall of the plains is stored and from which a number of springs and streams are sustained. The body of water is popularly known as the "underflow," and there is in some districts a mistaken impression that it has an inexhaustible source in the

Rocky Mountains. It will be of advantage to the community to have the conditions and limitations of this water supply set forth.

In the office the field notes of the previous season were written out, collections were numbered, arranged, and distributed, and a number of reports and scientific papers were prepared.

The detailed mapping by Mr. Gilbert of the Pueblo and Apishapa districts, in 1894 and 1895, and the reconnaissance of 1896, together furnished a body of information touching the underground water to which it seems desirable to give immediate publication. A report on this subject has therefore been prepared, and it appears in Part II of this Annual Report. This report sets forth the general geologic structure of the region and endeavors so to describe the formations that an intelligent man, even without technical geologic training, can obtain by local observation the information most important to him in determining whether or not to bore for artesian water. A district is outlined, 4,000 square miles in extent, within which the water-bearing layers of the Dakota sandstone lie less than 1,000 feet below the surface, so as to afford artesian water at moderate expense. In another district, about 1,500 miles in extent, the same reservoir of artesian water lies at depths ranging from 1,000 to 2,000 feet. Already a considerable number of successful wells have been drilled in this region, but the utilization of this mineral resource will probably be greatly extended in the near future. A general account of the sources and distribution of the ground water of the district is also given in the report.

The specimens of fire clays collected in previous years were examined in the chemical laboratory of the Survey, and those that appeared to have a favorable composition were afterward subjected to a fire test by Prof. H. O. Hofman, of the Massachusetts Institute of Technology. Several samples gave favorable results, and there is reason to believe that eventually the greater part of the fire clays used in the reduction works of the Arkansas Valley will be obtained in that region.

In addition to the work above described, Mr. Gilbert spent considerable time toward the close of the field season, and again in May and June, in the study of the Pleistocene history of the district about Niagara Falls, the northeastern part of New York State from Bangor to Lake Champlain, and a district in southeastern Michigan extending from Port Austin at the north to Wyandotte at the south. This work pertained almost wholly to features directly connected with the history of Niagara Falls, a report upon which will be prepared for incorporation in the Eighteenth Annual Report of the Survey. One of the phases of the subject to which especial attention has been given within the past year is the history of the changes in the drainage systems of Lakes Michigan, Huron, and Superior. Mr. Gilbert considers that he has unquestionable evidence that Lake Algonquin, the geologic ancestor of Lake Michigan-Huron, once discharged its waters by a northerly route, following the valley of the Trent River, and that the Detroit River, after carving out its channel, ceased for a time to flow. These results show that the volume of the Niagara River has undergone great variation. There is some reason to suspect that changes in relative heights of different parts of the basin, such as were connected with the past history of the river, may be now in progress. If they are, and if their tendency now is the same as in the past, they will eventually divert the drainage of the upper lakes from an outlet at Niagara to an outlet at Chicago.

Mr. Gilbert also gave some attention at intervals to the question of the determination of the total volume or mass of the sedimentary rocks of the globe and the study of the relative quantities of the more important sedimentary rocks, and also to the revision of proof sheets of a bibliography of geologic bibliographies, in course of preparation.

Hill party.—The party in charge of Mr. R. T. Hill was occupied in work in Texas, though Mr. Hill extended his field of observations into Indian Territory for the purpose of studying the relations of the known marginal portion of the Texas Cretaceous area to the Ouachita Mountains of that region. In company with Mr. Stanton, he examined the formations from Caddo to Denison, Tex., making a special study of a section in the vicinity of Denison. The same formations were also studied in northern Texas, points being visited in the vicinity of Fort Worth, Weatherford, Glencoe, and Waxahatchie. From Austin a trip was made by Messrs. Hill, Stanton, and Vaughan across the rough and difficult country to Brackettville, by way of Travis Peak, Marble Falls, Round Mountain, Fredericksburg, and Kerrville, for the purpose of reviewing the lower Cretaceous beds and their relation to the Paleozoic rocks of Burnet, Blanco, and Gillespie counties. En route the geology and geography of the Edwards plateau were studied, and also the region of the head-water drainage of the streams which rise in its southern margins. Important information was secured upon the conditions of occurrence of underground waters, and several new sources of supply were discovered.

Systematic work was begun upon the Brackettville sheet and carried forward until the areal geology was completed. The geology of this sheet will serve as the type of a large extent of country lying between the Pecos and Colorado rivers, an area of which we have little exact knowledge. After completing the Brackettville sheet, Mr. Hill's party took up the Nueces sheet, to the north, and completed the areal geology thereof. The areal mapping of the season includes about 400 square miles of resurvey and new work on the Austin sheet, 1,040 square miles of survey on the Brackettville sheet, and 1,035 square miles of the Nueces sheet. Reconnaissances were made of the Burnet, Blanco, Fredericksburg, Kerrville, Chispa, San Carlos, and El Paso sheets.

The principal scientific results of the season's field work are: The completion of the studies of the vast extent of Cretaceous formations lying east of the Pecos River, upon which Mr. Hill has been engaged, with the aid of his assistants, for a number of years; the obtaining of paleontologic material and stratigraphic data for the comparison and correlation of the beds of the uppermost division of the Cretaceous of the Rocky Mountain region with those of supposed synchronous age in the Eastern and Gulf regions of the United States; the final determination of the great Balcones scarp line, which forms such an important topographic feature in the south Texas region; the ascertainment of the exact character of the line of volcanic hills located approximately along the fault just mentioned; the final study of the Edwards plateau; and, finally, some comprehensive results relative to the post-Cretaceous erosion and deposition of the detrital formations of the Rio Grande embayment.

Among the economic results of the work are: The determination of the character and geologic occurrence of the commercially important asphaltum beds of southwestern Texas; the securing of full data touching the occurrence of underground waters in the great thickness of Cretaceous rocks of Texas; the determination of the age and position of the new and commercially valuable coal fields of San Carlos, in Trans-Pecos Texas, which, according to the researches of Messrs. Vaughan and Stanton, belong to a new coal horizon, so far as reported; and the procurement of additional data relative to the structure and extent of the upper Cretaceous and lower Tertiary coal basins of the Rio Grande embayment. Important facts were also secured bearing upon the origin of soils and the occurrence of flints, building stones, clays, etc.

Mr. Hill's work of the last field season represents the completion of a long-continued geologic study of the Cretaceous formations of Texas, and there are now in the office of the Survey data for the preparation of accurate geologic maps of the region. The material collected by Mr. Hill and his assistants will enable Mr. Stanton, in whose hands it has been placed, to prepare an extended monograph on the Cretaceous fossils of the Southwest. Mr. Frank Burns was employed during the field season, under Mr. Hill's instructions, as a collector, and he sent in 27 boxes of fossils.

Mr. Hill was engaged in the office the greater part of the winter and spring in the preparation of the text and maps of the Austin, Brackettville, and Nueces sheets. He also gave considerable time to the collection of data for and the superintendence of the preparation of a base map of the Texas region. This involved the complete revision of the astronomic location of various points, the political boundaries, and the drainage and physical features of the State. A large part of his time was given to the preparation of a monograph on the underground waters of Texas. Several special studies were also completed. These include a monograph on the gryphæate oysters of the Comanche series, and a revision of his previously published check-list of the invertebrate fossils of the Texas Cretaceous. A study was also made under Mr. Hill's direction, by Mr. George B. Shattuck, of Johns Hopkins University, of the fauna of the Shoal Creek limestone. Mr. Vaughan, in addition to his work on the atlas sheets, prepared a paper on the Texas coal fields of the Rio Grande region, carried to completion a memoir on the Eocene corals of the United States, and wrote a short paper on the geology and paleontology of northwestern Louisiana, which will be published as Bulletin No. 142.

Darton party.—Mr. N. H. Darton was employed for two months during the field season in North Dakota and South Dakota, obtaining data for a report upon the artesian-well prospects of the region. A general reconnaissance was made of all the well areas, and data were obtained touching the topographic and geologic features bearing upon the artesian water-supply problem. Mr Darton was assisted in the work in South Dakota by Maj. Fred Coffin.

During the winter a report was prepared in the office on the artesian waters of a portion of the Dakotas, which appears in Part II of this Annual Report. It includes all the available data relating to the wells of South Dakota, and also of the southern half of North Dakota, except the Red River Valley. The area in which artesian flows may be expected is indicated, and the distribution of head, pressure, and salinity is discussed. The structure, depths, and distribution of the water-bearing horizons are set forth in such manner as clearly to indicate the prospects in all portions of the area. Finally, there is a chapter on well construction and management.

ROCKY MOUNTAIN REGION.

This area embraces the Rocky Mountains and their foothills between the British and Mexican boundaries on the north and south, the margin of the Great Plains on the east, and approximately the line of the one hundred and nineteenth meridian on the west. In it five field parties were at work, as follows:

Weed party.—Mr. Walter H. Weed was engaged mainly in reconnaissance work in the northern part of Montana and Idaho and northwestern Washington, in company with the Director. Under detail from the Secretary of the Interior, he gave a short period to duty with the Commission appointed by the President to treat with the Blackfoot and Fort Belknap Indian tribes. While thus engaged he made an examination of the mineral character of the lands of the Little Rocky Mountains and secured sufficient data to enable him to prepare a geologic sketch map of the region. This shows the mountains to be an uplift of the Black Hills type, with an Archean core, upon which the Cambrian and other Paleozoic strata are upturned, the Mesozoic strata resting upon the flanks of the uplift.

The second region of which a reconnaissance was made is the isolated mountain group known as the Bear Paw Mountains. These consist of slightly disturbed Cretaceous beds, making a platform through which volcanic material has been forced to form a group of volcanics. The region is of great interest because it shows an excellent example of dissected volcanoes and because the rocks are of rare type and unusual association.

The economic work of the season consisted in the examination of the mineral resources of the region of the Little Rocky Mountains, where gold deposits as telluride ores are intimately associated with volcanic rocks; of the mines of the Bear Paw Mountains; of the geologic occurrence of the ore bodies of the Cœur d'Alene district, Idaho, where Mr. Weed was accompanied by the Director; and of the coal seams of the vicinity of Havre and Chinook, Mont., which completes the examination of the coal lands of the State so far as exploited.

Most of Mr. Weed's time in the office was occupied in the preparation of the Yellowstone Park material collected in previous years. The text and maps for two of the Montana folios were also advanced, so that they might be ready for publication on completion of the revision of the topographic base map. Prof. L. V. Pirsson was engaged the latter half of the year as a volunteer assistant in making a petrographic study of the volcanic rocks of the Highwood Mountains.

Eldridge party.—Mr. George H. Eldridge was detailed to make an examination of the mineral resources of the Uncompahgre and Uinta Indian reservations, in Utah, with especial reference to the deposits of hydrocarbon compounds of the asphalt series. He found that the area over which these hydrocarbons are present is about 90 by 150 miles—13,500 square miles—in extent, of which he examined in the route of investigation about 7,000 square miles. The chief deposits of the several varieties of asphalt were examined, with the exception of the deposits of wurtzilite and ozocerite, which were too deeply covered with snow to be accessible.

The scientific result of the investigation is a knowledge of the forms in which the hydrocarbons are found and of the geologic structure of the country. Among the economic results is a knowledge of the nature of the hydrocarbon deposits and a general definition of their extent, particularly with reference to uintaite (gilsonite).

Returning from the field, Mr. Eldridge proceeded to the preparation of the paper on the uintaite deposits of Utah, which he completed. It will be found in Part I of this Annual Report.

Emmons party.—The principal field work of Mr. S. F. Emmons and assistants, Messrs. J. E. Spurr and G. W. Tower, was the survey of the Aspen mining district of Colorado. The field work at Aspen was done by Mr. Spurr, with the assistance of Mr. Tower, except that Mr. Emmons gave some two weeks to underground exploration. In the course of the season Mr. Emmons also visited the Silver Cliff and Breckenridge districts of Colorado, the Butte district of Montana, and the Cœur d'Alene and Idaho basin regions of Idaho, the work in all these regions being reconnaissance preparatory to future detailed work.

The investigations in the Aspen district involved a very detailed examination of the surface geology and a reduplication of those observations beneath the surface to such an extent that the underground work far exceeded the surface work. Of areal work, 32 square miles were surveyed of the general geology of the mining district, 19 square miles of the detailed geology, and 3 square miles of detailed maps showing all mine workings. Of the above-mentioned areas, the first shows the relation of the mineralized area to the surrounding country which, for the most part, is not sufficiently mineralized to be of economic importance; the second shows the region known to contain available ore deposits, and the third includes all of the present productive mines.

The most important scientific results of the field work are those relating to the structural geology. The areal examination shows the results of intense compression of a series of sedimentary beds against a buttress of underlying crystalline rocks. The beds are greatly compressed and show reverse folds accompanied by faulting, and in the older and more rigid beds a varied system of faults, including strike, dip, and overthrust faults and some of an intermediate nature. Most of the faulting took place before the ore deposition, but a considerable amount has occurred since that period, and in several places the movement is still progressing. The study and elaboration of the field observations will undoubtedly result in the ascertainment of many additional facts of scientific interest in relation to the structural geology and the chemistry of ore deposition. Although the work at Aspen was undertaken at so late a date that many miners considered the district to be worked out, it is certain that the deductions to be made will be of great practical value to mine owners in enabling them to trace their ore with more certainty and in correcting certain misapprehensions as to the relations of the ore channels to structural features. The Aspen ore deposits have formed on fault planes, the ore channels often following those of more than one system of faults. These have been in many cases displaced by later faulting, so that their continuation in depth has frequently been entirely lost. It is anticipated that the deductions drawn from the Aspen work will clearly define not only the general localities where ore should be sought, but also those where it is not likely to exist. The value of the work in its influence upon new districts, by analogy through similar conditions in the

Aspen and in the new districts, can not be estimated, although it is anticipated that it will be of service to mining engineers in this connection.

At Silver Cliff Mr. Emmons ascertained facts of general scientific interest, which have been outlined if not fully determined. There is a remarkably rich vein of ore which does not reach the surface, but is met with at 1,850 feet below. In the 200-foot level of the mine there is a subterranean spring carrying in solution most of the metals found in the vein, together with other salts and acids. This may reasonably be considered to represent, if not the actual source, at least the continuation, of the action which formed the vein materials.

At Newlin Gulch, a small tributary of Cherry Creek, on the plains to the southeast of Denver, gold in apparently paying quantity has been discovered in the gravels of an ancient stream bed, at slight elevation above the modern stream. Mr. Emmons reports that the material of these gravels is a granitic detritus, entirely similar to that which formed the beds of the Monument Creek Tertiary, which covers a large area on the divide between the Arkansas and Platte river basins. This material evidently results from the breaking down of the Archean core of the Front Range of the Rocky Mountains, but neither the modern nor the ancient streams now known as Cherry and Newlin creeks head among these rocks, but in the Tertiary mesas at least 15 miles away. The gold placers, therefore, must be simply the concentrations of the Tertiary beds, and the original gold must have been carried out to this distance from the mountains in the waters of the Tertiary lake. The study of such a mode of occurrence of gold is interesting, in view of the mode of occurrence of the gold at present derived from the South African conglomerates, which are regarded by some as fossil placers.

Mr. Emmons's examination of deposits of gold at Breckenridge was not completed, because of a heavy fall of snow in the latter part of September.

Owing to the fact that he had suffered a serious illness in the spring, from which he had not entirely recovered, Mr.

Emmons was not able to take the field in July, and therefore he completed in the office the report on the Mercur mining district, and also wrote an introductory chapter for the monograph on the Denver Basin (Monograph XXVII). On his return from the West, early in October, he resumed office work, giving his attention first to a revision of the monograph on the Denver Basin, which is now in press. The special geologic map of the Ten Mile district of Colorado was taken up and prepared, together with explanatory text, for publication as a folio of the Geologic Atlas, and a paper was written upon the mines of Rosita Hills and Silver Cliff, in Custer County, Colo., which is published in Part II of this Annual Report.

Mr. Spurr, assisted by Mr. Tower, completed the report and maps of the Aspen district before starting for Alaska on June 1. Mr. Emmons observes that the region treated of, which is not of great areal extent, presents a degree of structural complexity unequaled by any area of similar extent that has come under his observation. Mr. Spurr made a complete microscopic study of the various rocks and vein materials, which, supplemented by chemical examinations made in the laboratory of the Survey, has enabled him to trace out in detail the probable process by which the ores have been deposited. This required a very elaborate system of maps of the underground workings as well as the surface features, upon which the observations might be platted and the results worked out. The surface maps upon which the geologic boundaries have been laid down and the phenomena of deformation indicated (such as folding and faulting) are as follows:

Class.	Number of maps of folio size.	Scale of map.	Area in square miles.	What it represents.
1	3 whole sheets.... 2 half sheets	300 feet = 1 inch or 1:3,600.	3.2	Includes all at present productive mines and shows principal drifts.
2	3 whole sheets.... 1 half sheet	800 feet = 1 inch or 1:9,600.	19.16	Includes all the region known to contain valuable ore deposits.
3	1 whole sheet......	2,640 feet = 1 inch, or 1:31,250.	32.16	Shows relation of mineralized area to the surrounding country.

It is estimated that 190 miles of geologic boundaries have been laid down on these maps. They will be published in atlas form, and each map will be accompanied by one or more sheets of transverse sections, showing the underground relations of the various rock formations outlined in the surface maps and the positions of the ore bodies with reference to them. The report will be published as one of the monographs of the Survey, with an atlas containing about 29 sheets.

Cross party—Mr. Whitman Cross was engaged in the mapping of the areal geology of the Telluride district of Colorado. The eastern half of this district includes the high, rugged, western front of the San Juan Mountains, and lies, for the most part, 10,000 feet above sea level, while the central-western part is from 9,000 to 10,000 feet in elevation. Sixty-four mountain points lie above 13,000 feet and four above 14,000 feet. A few canyons cut to below 8,000 feet in several places.

With the assistance of Messrs. H. S. Gane and E. C. E. Lord, Mr. Cross mapped 245 square miles of the rugged region above indicated. He made six divisions of the surface volcanic rocks. The study of these is the first step toward working out the volcanic history of the great San Juan region.

The studies of the field season make it clear, from the formations of the Telluride area, that there must have been at least two centers of eruption from which the material of these volcanic formations came. The principal formation is a great series of well-stratified tuffs and conglomerates, 1,500 to 2,500 feet in thickness, which extend over hundreds of square miles. It is the first of the series, and apparently a water-laid formation throughout.

Three large laccolites were identified in the Cretaceous rocks, and five great, irregular diorite bodies cut up through all the formations of the region, rising to more than 14,000 feet in several cases. One of them forms the core of the Mount Wilson group. The Cretaceous and Tertiary rocks through which the diorite penetrated form the lower portion of the mountains.

The sedimentary formations include the Trias, Jura, Dakota, Colorado, Montana (?), and a probable Eocene formation. The base of the Juratrias was not determined, but the formation was identified by the presence of saurian teeth and bones. The upper portion of the Jurassic is a series of clays, sandstones, and marls, 700 feet in thickness. The Cretaceous includes the Dakota and Colorado formations. The Dakota formation is about 100 feet thick and contains a workable coal seam. The Colorado is represented by 2,000 feet of shales that occur above the Dakota. The Montana formation has not yet been clearly defined. The Eocene conglomerate occurs unconformably above the Dakota-Montana shales, and varies from 200 to 1,000 feet in thickness. It traverses the entire section unconformably from the Trias to the summit of the Cretaceous. It is a coarse conglomerate, consisting of granite, quartzite, and schist of Algonkian types, limestones, red sandstones, and an eruptive rock unlike any known in place in the district. The formation extends beyond all borders of the Telluride area and probably overlaps the Paleozoic section to the Algonkian rocks of the Needle Mountains. It is referred tentatively to the Eocene, though no fossils have been found.

As the work was purely areal geology, there have been no special developments of economic bearing, except in the correct understanding of the eruptive geology of the district, the analysis of which will render possible a recognition of either the differences or the identity of conditions among ore deposits in different parts of the area. At present mining men are more or less confused by the immensity of the volcanic formations of the San Juan region, and it is anticipated that the geologic map will be of service to them in the development of the various silver and gold mines of the area.

On his return from the field Mr. Cross first completed the revision of certain chapters of the monograph on the Denver Basin. He also revised the report upon the geology of Silver Cliff and the Rosita Hills, Colorado, which is published in Part II of this Annual Report. He likewise advanced the bulletin on the geology of the Pikes Peak district, worked up the material collected in the Telluride region of Colorado, and examined the literature relating to the San Juan Mountains.

Toward the close of the year steps were taken to establish within the Survey, for the use of geologists and petrographers, a comprehensive reference collection of rocks, the expectation being to facilitate the progress of the work of the Survey and raise its standard. To organize this collection, a committee of three was appointed by the Director, consisting of Messrs. Cross, Lindgren, and Diller. Mr. Cross was made chairman of the committee, and considerable time was given by him to the consideration of that subject.

Hills party.—Mr. R. C. Hills continued the survey of the coal and iron areas of southern-central Colorado. He surveyed and mapped 343 square miles and resurveyed 260 square miles. Further evidence was obtained on the relative age of the successive eruptions of the Spanish Peak region, and outlines of the boundaries of the Cretaceous and Eocene groups were determined within the area surveyed. It was found that the Dakota terrane overlapped the supposed Jurassic rocks, and that the latter, in turn, overlapped the supposed Trias along the southeastern shore border of the Wet Mountain Range.

Among the economic results secured was the revision of the boundary of the coal-bearing Laramie terrane on the Walsenburg and Trinidad sheets. Observations were also made on the silver-lead veins of Spanish Peak, and the so-called tin deposits at the southern extremity of the Wet Mountains were investigated. In the latter investigation no evidence was found of the existence of the ores of tin.

Hague party.—Mr. Arnold Hague continued in the office the preparation and study of the data and material collected during his nine years of surveys in the Yellowstone National Park. The final work upon the atlas folio was completed and the geologic sheets and explanatory text are now going through the press. The monograph on the park will be published in two parts. Part II, which is mainly descriptive in its treatment of the subject, is about ready for the press. The areas of sedimentary rocks which surround the park plateau are developed in the Gallatin, Snowy, and Teton ranges and in the region of Huckleberry Mountain and Big Game Ridge. The several chapters were written by Mr. W. H. Weed, Prof. J. P. Iddings, and Mr. Hague. A large part of the volume is from the pen of Professor Iddings, who deals with petrographic investigations from different points of view, and gives an analytical study of the composition of the igneous rocks found in the region. He also has chapters on the volcano of Electric Peak, in the Gallatin Range, and the Crandall volcano, in the Absaroka Range.

All the invertebrate paleontologic material gathered during the progress of the survey is treated in chapters by Mr. T. W. Stanton, Mr. G. H. Girty, and the Director. Mr. F. H. Knowlton furnishes a chapter on the fossil flora of the park, describing in detail the collections made from time to time in this region. They include a limited but characteristic flora from the Laramie and a rich and varied flora from the Tertiary. His work is illustrated by 45 plates of drawings of the new species described by him in the text. The various chapters by the different authors have been submitted. The illustrations, which include maps, sections, photographs, photomicrographs, and woodcuts, are in an advanced stage of preparation.

It is anticipated that another season in the field will be required to perfect the geologic work necessary to complete the areal mapping of the country embraced by the Crandall Creek and Ishawooa atlas sheets, lying in the forest reservation to the east of the park.

PACIFIC REGION.

This region embraces the territory lying between the Pacific Coast on the west and approximately the line of the one hundred and nineteenth meridian on the east. In it six parties were at work, as follows:

Turner party.—Mr. H. W. Turner continued the mapping of the areal geology of the Gold Belt of California, being aided by Mr. F. L. Ransome, a temporary assistant. Of the Sonora sheet, 940 square miles were mapped, and 120 square miles of the southeastern portion of the Big Trees sheet. An extensive collection of gneisses and granites was made in the canyon of the north fork of the Mokelumne River, in the northern part of the area.

Among the scientific results may be mentioned the structural features of the Sonora district found in the disposition of the limestone masses about the mouth of the north fork of the Tuolumne River. It was also found that the granite was younger than the surrounding schists, while the gneisses and sheared granites of the northern part of the area of the Big Trees sheet appear to show that there is there an older set of rocks, possibly pre-Paleozoic in age.

The Sonora sheet covers an area in the heart of the Gold Belt of the Sierra Nevada. Numerous gold-quartz mines were located and defined, and they will be represented on the economic sheet of the Sonora folio. The limestone and marble masses will likewise be indicated. The marble has been largely quarried and found to be of economic importance. There is also an abundance of granite and sandstone suitable for building purposes.

Since his return from the field Mr. Turner has been engaged in preparing a paper entitled, Further Contributions to the Geology of the Sierra Nevada, which is printed in Part I of this Annual Report. He has also continued his study of the rocks of the areas surveyed, and it is anticipated that the Downieville folio will be ready for engraving in a very short time.

During the winter and spring Mr. Ransome was occupied at intervals, the greater part of the time as a volunteer assistant, in studying thin sections of the rocks collected by him in the Sonora area and in preparing the text of the Sonora folio for publication.

Lindgren party.—Mr. Waldemar Lindgren, who was assisted by Mr. H. C. Hoover, also worked in the Gold Belt of California a considerable portion of the season. A reconnaissance was made of about 200 square miles on the Sierraville sheet, and one of 500 square miles on the Carson and Markleville sheets. In addition to revising about 150 square miles, he completed the geologic work on the Colfax sheet.

The principal results obtained bear on the structural geology of the eastern slope of the Sierra Nevada. The great faults along the eastern base have been mapped, and data have been obtained for determining the amount of throw and the character of the dislocation. Two distinct dislocations were recognized, one corresponding to the Neocene baselevel, and the other of older date, probably the Cretaceous baselevel. The season's work completed the study of a trip across the Sierra Nevada, from the Sacramento Valley to the Great Basin, between the parallels 38° 30′ and 39° 30′.

In July Mr. Lindgren made an examination of certain reported gold-bearing gravels near Tacoma, Wash., under special instructions from the Secretary of the Interior, and in the latter part of December a reexamination was made of certain portions of the same district. The results of these examinations have been communicated to the Department.

Mr. Lindgren's office work was confined to the period between January 25 and July 1. It consisted principally in the preparation of the Pyramid Peak sheet for the engraver and of the report on the gold-quartz veins of Nevada City and Grass Valley which is published in Part II of this Annual Report.

Branner party.—Dr. John C. Branner was engaged in reconnaissance work upon the Palo Alto, San Mateo, San Jose, and Mount Hamilton sheets, California, with the object of obtaining a general knowledge of the geology, to aid him in making a detailed survey of the Palo Alto sheet. The work was carried forward in the foothills and in the mountains south and west of Palo Alto and in the Santa Clara Valley, where data were obtained by means of artesian-well borings.

The only office work undertaken was the study of maps and the preparation of field notes.

Lawson party.—Dr. A. C. Lawson, assisted by Dr. J. C. Merriam and Mr. W. S. T. Smith, continued the study of the geology of the region adjacent to the Bay of San Francisco, in California. Three hundred and four square miles of new territory were mapped, which practically completes the survey of the five sheets in the vicinity of the Bay of San Francisco.

The work is of scientific and economic importance in connection with the question of artesian water supply to the numerous towns within the areas. The study of the structure and stratigraphy will also advance the knowledge of the nature and origin of the oil and asphaltum which abound in the siliceous shales of the region and enable the geologist to advise more intelligently in regard to prospecting for these products. Information was also acquired touching the distribution of limestone, building stone, clays, etc.

At intervals during the winter, Dr. Lawson wrote out the field notes and studied the material collected in his expeditions to the field.

Diller party.—The work of Mr. J. S. Diller in Oregon was wholly reconnaissance in a new region, as there were no topographic maps ready for complete geologic work. The fields of which a preliminary study was made embrace three continuous districts: (1) The Coast Range of Oregon, from the Columbia to the forty-third parallel, an area of about 9,000 square miles. (2) The northern border of the Klamath Mountains, within the region covered by the Roseburg sheet, about 871 square miles. (3) Several distinct points on the western slope of the Cascade Range, including about 100 square miles. The first-named region was studied chiefly on account of its coal fields; the second, on account of its mineral wealth and its nearness to a populous center, of which a good topographic map has just been completed; and the third, to determine the age and composition of the Cascade Range and its relation to the Cretaceous strata bordering the Klamath Mountains. Specimens were collected from 445 localities, fossils being well represented.

The principal scientific results obtained in the first district visited were the three sections made in the Coast Range, the Nehalem, the Yaquina, and the Coquille. These show the position, structure, and history of that portion of the range.

In the Nehalem section, well exposed along the Nehalem River, the middle portion of the Coast Range is composed chiefly of volcanic rocks, with flanks of Tertiary shales and sandstones, gently dipping away from the range. The structure of the range is essentially anticlinal, with a volcanic core. The volcanic conglomerates of the core contain a few fossils, apparently of Eocene age, and the association is such that two things are evident: (1) During that portion of the Eocene period represented by the fossils the Coast Range was not yet raised above the sea; (2) the locality was then the scene of vigorous volcanic activity. In the Yaquina section the composition and structure of the range is similar to that on the Nehalem, except that it is not symmetrical. The Coquille section is quite unlike either of the others. The volcanic rocks are a minor feature of the range, and the older auriferous slate series appear just south of the Coquille, where the Klamath Mountains begin.

The history of the Coast Range north of Coquille, as recorded in its rocks, shows that a period of volcanic activity was followed by a long period of sedimentation, with more or less volcanic eruption and orographic movement, which gradually culminated, before the close of the Pliocene, in raising the Coast Range above the sea. Subsequently the land was reduced by erosion to a peneplain, and again uplifted, the successive stages being marked by terraces upon the coastal slope. The drowned rivers of the Oregon coast show that the final movement of the land has been downward, in some cases admitting the tide for 20 miles up the narrow valleys of the rivers.

The discovery of Paleozoic fossils in the Roseburg region is of special interest, as it is the only locality in Oregon west of the Cascade Range where such fossils have been found. The strike of the rocks throughout the Roseburg district is southwest and northeast, at a considerable angle to the general trend of the Cascade Range. The gold-bearing slate series extend into its western flank, as if passing through that range to the Blue Mountains of eastern Oregon, where the same rocks occur.

The examination of the Cascade Range at Ashland, on the middle fork of the Willamette and the Columbia, shows that that portion at least is composed of post-Cretaceous lavas. The Cretaceous rocks underlie a large portion of the range, and the most vigorous stage of volcanic activity was in Miocene time.

The economic results of the work consist principally in the reconnaissance of (1) the coal fields of western Oregon, (2) the iron-ore deposits of the Coast Range, and (3) portions of the auriferous slate series in middle-western Oregon.

The coal fields of western Oregon are four in number, viz, the Upper Nehalem, of Columbia County; the Lower Nehalem, of Clatsop County; the Yaquina, of Lincoln County, and the Coos Bay, of Coos County. Besides these there are numerous outcrops of coal of minor importance.

The Upper Nehalem coal field is drained by the portion of the Nehalem River lying east of the Coast Range in Columbia County, and the coal has been prospected chiefly in Pebble Creek. The field is about 13 miles long and from 1 to 2 miles wide, and contains at least two coal beds worthy of consideration. One is 9 feet and the other over 6 feet in thickness. The upper and larger bed, being above drainage and nearly horizontal, is conveniently situated for economic mining, and only awaits greater facilities for transportation to develop what may prove to be an important source of coal for Portland. The chemical analyses of these and the other coals of Oregon are not yet completed.

The Lower Nehalem coal field lies near the coast, a few miles southwest of Nehalem post-office. Its length is 5 miles and its breadth one-fifth as great. The quality of the coal is good, but its thickest bed is not known certainly to exceed 22 inches, and lies between soft strata inclined at a considerable angle.

The Yaquina coal field lies just west of Depot Slough, in Lincoln County, and covers an area of about 5 square miles. Its best bed of coal is good, and it is said to be 3 feet in thickness.

The Coos Bay coal field has a known area of certainly not less than 100 square miles. It contains at least two beds of coal 5 feet or more in thickness, and three mines are in active operation. The Newport has been running for more than thirty years, and has removed in the last fifteen years 700,000 tons of coal. It was estimated that the Beaver Hill mine, started in 1895, would produce at least 12,000 tons of coal by the close of that year.

Numerous other less prominent coal outcrops have been examined in Oregon—notably near Cape Arago in Lincoln County, and in Camas Mountain, near Callahans, and on the north fork of the Umpqua River in Douglas County—which do not promise to be of considerable commercial importance.

The iron ores of the Coast Range have been found in workable quantities in but few places, notably at Oswego and Scappoose, near Portland. They have also been found in considerable quantities in several places on the west fork of Dairy Creek, in Washington County, and along the upper waters of the Nehalem, in Columbia County. Magnetite and similar ores also occur in the Klamath Mountains, in Josephine County, but of the extent and purity of these ores little is yet known.

The auriferous slate series of middle-western Oregon is in two large areas, one in the Klamath Mountains, in the southern portion of the State, and the other in the Blue Mountains of Oregon. In these older rocks the precious and baser metals are found—gold, silver, platinum, and nickel. In the Bohemia district, north of Ashland, a number of stamp mills are at work, and others are under construction. The ore is chiefly free-milling quartz, which forms numerous veins in the country rock, which is of igneous origin.

The promising prospects for cinnabar, reported from east of Oakland, merit thorough investigation. This district was formerly one of considerable mining activity, and it is possible that cinnabar mining might be resumed to advantage.

In the office Mr. Diller prepared a report upon the geological reconnaissance in western Oregon, which appears in Part II of this Annual Report. He also prepared a brief text, with illustrations, to be printed as a part of the special map of Crater Lake. Crater Lake is on the summit of the Cascade Range, and is in a public reservation. It is encircled by cliffs ranging from 500 to 2,000 feet in height, has a depth of 2,000 feet, and is one of the great natural wonders of the United States.

Mr. Diller was also engaged in the preparation of the text to accompany the Educational Series of Rocks. Nearly 50 rock specimens were described, and the work is now nearing completion. In addition to the work already noted, Mr. G. K. Gilbert has described the glacial material of the collection (3 specimens), Mr. Bailey Willis the specimens illustrating rock deformation (2) and those of peat and coal (4), Mr. W. S.

Bayley a number of specimens of metamorphic rocks, Mr. H. W. Turner the specimens illustrating contact metamorphism (2), and Mr. G. P. Merrill, of the National Museum, the specimens illustrating rock decay. During the year 250 specimens of each of six kinds of rocks for the Educational Series have been collected, 802 have been trimmed, and 13,508 numbered.

In addition to his other work, Mr. Diller continued in charge of the Petrographic Laboratory, being assisted by Mr. E. G. Paul, in immediate charge, and Messrs. F. C. Ohm and W. S. Robbins. During the year 3,970 thin sections of rocks were made, and 940 specimens were sawed, polished, or otherwise prepared for study.

Willis party.—Mr. Bailey Willis, assisted by Mr. G. O. Smith, was engaged principally while in the field in reconnaissance work in northwestern Washington. He examined the glaciers on the northern and western slopes of Mount Rainier, the Wilkeson and Green River coal fields, the Snoqualmie section of the Cascade Range, the gold and silver districts of Silver Creek and Monte Cristo, and the iron-bearing schists and the coal measures of the Skagit between Sauk and Hamilton.

Mr. Willis found that the Puyallup glacier had retreated at least 600 and possibly 1,000 feet from the position it occupied when he examined it in 1883. On the Carbon River glacier the evidence of shrinkage observed consisted in the difference of level between the diminished glacier and the crest of its lateral moraine. The recession of the glaciers is accounted for in part by the fact that there was much less precipitation during the last winter than during the previous winters, and consequently less snow upon the slopes of Mount Rainier than had been observed any time since the region was settled. In consequence of their great recession the glaciers are particularly dirty; indeed, portions of the Carbon River glaciers are so covered with stones and gravel as to give the appearance of a river bed rather than an ice mass. Along the lower course of the Carbon River glacier there is record of an earlier and larger stage of the glacier in the existence of lateral moraines, which lie outside of but parallel to the modern moraines and are covered by a growth of large trees.

The coal-bearing strata of the Puget group are so destitute of recognizable horizons that in the presence of the universal covering of gravel and forest it is a hopeless task to work out the stratigraphy without the aid of fossils. Accordingly, two well-known sections were carefully examined and collections made, which were accurately identified with certain horizons, in the hope that their examination might enable the geologist to discriminate between the older and the younger beds.

A section was examined on the line of the south fork of the Snoqualmie River, from the city of Snoqualmie to the summit of the range. At the head of the south folk the vicinity of the Snoqualmie Pass furnishes occurrences of magnetic iron ore in fissures in the granite. In the immediate vicinity there are highly metamorphosed black slates containing leaves of Miocene age, and it has not yet been determined whether the granite is older or younger. If younger, the metamorphism of the slates and the deposition of the magnetic ores might be looked upon as contact phenemena; if older, the metamorphism and deposition of the iron ore must be attributed to some external cause. The economic value of the magnetic iron of this vicinity is likely to prove great, provided it shall be shown that the ore bodies are extensive and that they are not seriously contaminated with sulphur.

The Monte Cristo mining district contains the most extensive development yet made on the precious metals in Washington. The country rocks are in part black slates, conglomerates, and limestones of Mesozoic age, intrusive granites, porphyrites, and diorites, and breccias and spherulites of more superficial volcanic eruptions. The minerals are deposited in cavities due to faulting and brecciation of the rocks, and form bodies varying from minute stringers to deposits 2 or 3 feet in thickness. They consist of sulphides of iron, arsenic, lead, and zinc in varying associations, carrying both gold and silver. The greater part of the gold is contained in the arseno-pyrite. The reconnaissance served merely to indicate the necessity for detailed geologic mapping with reference to the different kinds of rocks and the structural features. The mechanics of the rock deformation plays an important part in determining the occurrence of the minerals, and a careful study of this region should be helpful to prospectors throughout the northern Cascade Mountains; the district is a typical one for that region. Gold and silver ores occur on both sides of the range, from Snoqualmie Pass to the British boundary and beyond, and whatever is done in one locality, like Monte Cristo, will serve as a guide to intelligent prospecting throughout the whole region. As the phenomena appear to be mechanical rather than volcanic or sedimentary, a study of the mechanism of faulting is particularly needed.

The iron-bearing schists of the Skagit form an immense body, having a nearly east-west strike and an apparent thickness of several miles. Their limits are not well determined. The schists and the associated siliceous iron ores are very closely related, in character and in the origin of the ores, to the Lake Superior siliceous deposits, but they rest upon a massive limestone in which fossils are discovered. These appear to be crinoids, and suggest a late Paleozoic age. An effort was made to discover localities favorable to the occurrence of the rich, soft ores which may reasonably be expected to have been formed from the decomposition of the carbonate of iron contained in the schists, but in the absence of maps, and on account of the extremely inaccessible character of the region, no progress was made in this direction. It will, however, be pointed out in a general account of the work, to be published later, that these iron ores may be looked for under certain conditions of structure and along the contact with the limestone, and it is hoped that prospecting thus directed may result in the discovery of ores which are much needed in the development of the State.

Mr. Willis's examination of the region about Mount Rainier intensifies his former impression that it is unique in character and should be set apart as a national park.

During the winter Mr. Willis arranged his field notes, and Mr. Smith made a petrographic study of the volcanic and metamorphic rocks. Mr. Willis's time was given mainly, however, to the work of editing geologic maps, which will be reviewed on a subsequent page of this report.

Becker party.—Dr. George F. Becker, assisted by Mr. C. W. Purington, was engaged in the examination of the gold deposits of southern Alaska. Associated with Dr. Becker was Dr. W. H. Dall, who had immediate charge of an examination of the coal resources. The instructions to the party were to examine the gold and coal deposits in the vicinity of the shore line and islands along the coast of the Territory, and not to attempt to penetrate into the interior.

Dr. Becker and Mr. Purington examined the Treadwell mine, on Douglas Island, and found that the mine was in slates of sedimentary origin, probably of Triassic age, and that it had been penetrated by a heavy dike of diorite or tonalite and by two other intrusive masses. The last of these is a rock of basaltic character, and its eruption seems to have occurred at the same time as the mineralization. Both the diorite and the slate were ruptured along a zone which is at some points several hundred feet in width, and the interstitial spaces have been filled with ore. In the diorite the masses were in great part reduced to fragments, and these have been decomposed and impregnated. In the slate the fractures mostly followed the cleavage, and the deposit there assumes the form of a "stringer lead." The claims to the southward of the Treadwell are controlled by the same company, and are profitable, but the next claim to the northward is said to be too poor to pay. The ore of Treadwell averages only $2.50 to $3 per ton, but, owing to the enormous scale of the workings, there is a large profit in working it.

The Silver Bow basin lies about 3 miles north of east of Juneau. A considerable number of small veins of rather rich ore occur in the southern side of the basin. The basin was formerly occupied by a large glacier. After the retreat of the glacier the basin was occupied by a lake, and the lake beds are successfully worked for gold by the hydraulic process.

Sheep Creek basin is separated from Silver Bow basin by a divide, and the same series of quartz veins extend into it. About 55 miles to the southeast of Juneau, at Sumdum, there is a very promising vein which is yielding good bullion, although the property is only just being developed. At Seward City, near Berners Bay, about 50 miles north of Juneau, there are also veins which are extremely rich at some points and are yielding gold. On Admiralty Island, about 30 miles from Juneau, there are promising veins, on which it is expected that mining will be commenced during the summer of 1896. Near Sitka, especially along Silver Bay and in the country to the southeast of it, there are numerous veins, some of which have yielded a little gold. The conditions do not warrant an opinion as to their future.

At Yakutat Bay, just to the eastward of Mount St. Elias, there has been some beach mining, as there has also been along the west shore of Kadiak Island. The ease of working and the unlimited supply of sand make beach mining on the western coast of North America very attractive, but the capriciousness of the distribution of pay streaks and the difficulty of saving the gold commonly rob such undertakings of success. The amount of gold which occurs in this manner in the sand is enormous, but as yet there are few if any reliable records of large profits having been made from beach mines, either in Alaska or to the southward.

On Kadiak Island, in Uyak Bay, there are several promising-looking gold-quartz veins, 2 feet or so in thickness, upon which prospecting is now going on. Stream gravels are also being worked on Turn-again Arm, at the head of Cook Inlet. The only successful working was on Bear Creek, but according to the best information that Dr. Becker could obtain the average results were not more than $5 per day per man. A later report, received after Dr. Becker's visit, is that richer gravel has been discovered near the head of Turn-again Arm.

The island of Unga is in the Shumagin Archipelago, about a thousand miles south of west from Sitka. Near Delaroff Bay, on this island, is the Apollo Consolidated mine, which is now yielding at the rate of over $300,000 a year. The ore occurs in interstitial spaces in a crushed zone of andesite. It averages between $8 and $9 per ton, much of the gold being free, though heavy bunches of sulphurets are of frequent occurrence in it.

Although auriferous quartz has been found on the island of Unalaska, nothing like a mine has yet been discovered.

Dr. Dall first examined the coal field surrounding Kootznahoo Inlet, after which he coasted along the south side of the Alaskan peninsula to the head of Cook Inlet, and thence to Kachemak Bay, where extensive deposits of brown coal occur. Thence he journeyed via the Shumagin Islands to Unalaska, where the investigation was virtually brought to an end. August 29 found Dr. Dall at San Francisco, where he spent a short time gathering coal statistics.

In the course of the journey above outlined, Dr. Dall visited all localities where work is or has lately been in progress, either in prospecting or mining the Alaskan coals, south of Bering Sea in Alaska. Specimens were obtained for analysis and all the accessible economic data were collected. The localities bordering on Bering Sea and the Yukon, and those north of Bering Strait, were not visited, on account of the lack of means of transportation.

The results may be briefly summarized as comprising (1) the collection of a large mass of useful economic data and new information on the Alaska brown coals; (2) the establishment of the fact that large fields of a fairly good quality of brown coal exist on the eastern shores of Cook Inlet, and that veins of economic value exist on the south shore of the Alaskan peninsula; (3) that the coals of Alaska are all brown coals, no anthracite or Paleozoic bituminous coal having yet been discovered; and (4) that, with the use of sufficient capital and proper business methods, a California market for the coals, at prices commensurate with their value, should be found.

Further particulars touching Dr. Dall's work will be found in his detailed report in Part I of this Annual Report.

It is appropriate here to acknowledge the courtesy of the Secretary of the Navy, and of Capt. A. R. Couden, of the U. S. S. *Pinta*, for courtesies in conveying the party from point to point along the Alaskan coast, and to Captain Moore, of the Coast Survey steamer *Patterson*, by whose aid the coal fields surrounding Kootznahoo Inlet were explored.

On his return from the field Dr. Becker began the preparation of a report upon his field work. This work he continued until about April 1, when, an unusually fine opportunity offering for an examination of the gold fields of South Africa and an investigation of the mode of origin of the gold of that region, a leave of absence without pay was granted him for the remainder of the fiscal year.

GLACIAL INVESTIGATIONS UNDER PROFESSOR CHAMBERLIN.

Prof. T. C. Chamberlin was continued in charge of work upon the glacial deposits of the United States. Areal work in New York resulted in the completion of the survey (280 square miles) of the New York portion of the Greenwood Lake and Ramapo sheets, by Mr. C. E. Peet. That assistant also did considerable work on the Staten Island and Tarrytown sheets, and extended a reconnaissance up the Hudson and Champlain valleys to the Canadian border.

The scientific results of the complete mapping of the sheets mentioned will throw light on some of the problems of the drift, prolonging into New York the location of the axis of the Hudson River lobe of the ice sheet from that determined in New Jersey. It will show the direction of ice movements, the drainage during the retirement of the ice, the temporary halting places of the ice front, with an accurate delineation of the areas of stratified gravels and sands and of unstratified drift, the locations of outcrops of rock, of areas of humus and peat, the delineation of the alluvial plains of the streams, and the subdivision of some of these classes of deposits.

The economic results will be those directly resulting from the accurate mapping of the different classes of deposits mentioned, the determination of the northward extension of the Pleistocene clays of the Hackensack Valley, and the accumulation of a mass of facts relating to the character and thickness of the deposits mapped. All of these data have an important bearing on questions of water supply and on all questions pertaining to the utilization of the surface deposits in any way by the people. The reconnaissance in the Hudson and Champlain valleys determined the origin, distribution, and thickness of the Hudson River and Lake Champlain clays. Facts were accumulated touching the extent and thickness of the clays and the distribution of the sands for tempering clays in the manufacture of brick and terra cotta, and a way was prepared for the rapid mapping of these extensive deposits. These results are all of economic importance, as New York State stands sixth among the States producing valuable clay products, and the Hudson Valley supplies a large percentage of the clay product of the State. The accessibility of these clays to the market for the articles produced from them, the high price at which the clay lands nearest the market are held, and the probability of the clay proving to be a valuable fertilizer for certain areas of dune sand along the Hudson, thus reclaiming those areas and making them profitable for cultivation, render the accurate mapping of these deposits desirable.

In Pennsylvania, Mr. H. B. Kummel mapped the Pleistocene deposits of that portion of the Delaware Water Gap and Easton sheets which lies on the western side of the Delaware River, the portion on the eastern side having been previously mapped.

The scientific results of this work, other than those immediately implied in the mapping of the formations, are chiefly the determination of the difference in age between the moraine which crosses the Delaware at Belvidere and glacial deposits found on the uplands extending some 25 miles more or less to the south of these, which are much older.

In Indiana, Mr. A. H. Purdue made a detailed map of the Pleistocene formations in the Iroquois Valley, embracing about 400 square miles. The chief scientific object sought was the determination of the mode of origin of the sands which abound in that region and their significance respecting the conditions which prevailed during the later Pleistocene period. The areal work will also be serviceable in delimiting the comparatively barren, sandy tracts, distinguishing them from the fertile, loamy tracts on the one hand, and from the marshy and meadow tracts on the other.

The services of Prof. R. D. Salisbury have been chiefly devoted to the investigations carried on by the State Survey of New Jersey under the system of cooperation entered into between that Survey and the National Survey. He, however, gave a short time in June, 1896, to reconnaissance in the territory immediately adjacent to the cities of New York and Philadelphia, with a view to rendering advice and assistance in the detailed mapping of these regions, in progress under Mr. Kümmel and Mr. Knapp, respectively, and to secure a more perfect coordination with the work of the New Jersey Survey.

Mr. H. C. Cowles's work consisted principally in a search for fossils in the inter-Glacial soils and vegetable beds of selected points in Iowa and Minnesota.

Mr. Frank Leverett was employed chiefly in the preparation of a voluminous report upon a large area occupied by the Illinois glacial lobe. A few short visits were made to different points of the field to obtain additional data. He also prepared a map, covering the whole of Illinois, showing the distribution of the drift formations.

Later in the year Mr. Leverett made an important discovery with reference to the ancient drainage of the Virginias and eastern Kentucky. It has for some years been known that the various streams constituting the upper part of the Missouri River once sent their waters toward the northeast, and that they were diverted in Pleistocene time by the great ice sheet which occupied their lower valleys and caused them to turn southeastward. It has also been known that the Monongahela and various branches of the Allegheny formerly discharged toward what is now the basin of Lake Erie, and were caused to unite in the formation of the Ohio River by a similar interference of the Pleistocene ice sheet. Mr. Leverett has now found a pre-Glacial channel running from the Ohio at Wheelersburg to the Scioto at Waverly, and brings to bear a variety of accessory data showing that the Kanawha, uniting with other streams in the western part of West Virginia and the eastern part of Kentucky, ran northward toward Lake Erie along a line partially coincident with the course of the south-flowing Scioto. This makes the Eocene drainage basin of the St. Lawrence include the head waters of the New River in northwestern North Carolina.

The most important economic results of the work in Illinois consist of (1) the mapping of the soils and subsoils, which will furnish a basis for a comparison of the results of farming and for the intelligent use of agricultural processes, fertilizers, etc., and (2) the collection and classification of very large numbers of well sections, from which important generalizations respecting the underground courses and the possibilities of water supply are being deduced.

Professor Chamberlin's personal work in field and office consisted largely in the supervision of the work of his associates, which also embraced the study and criticism of reports submitted. About one month of his time was spent in the field in a study of the Pleistocene formations along the Illinois River between the drainage canal and Lasalle.

In the office Mr. Leverett was engaged for nearly five months, in the early part of the year, in the preparation of a report on the Illinois glacial lobe. This work was suspended in December, in order that he might prepare, under the immediate direction of Mr. F. H. Newell, the chief hydrographer, a special paper upon the water resources of Illinois, which paper was completed the last of April and appears in Part II of this Annual Report. The other assistants were engaged from time to time in writing out their field notes and preparing data for study and publication.

FIELD AND OFFICE WORK BY THE DIRECTOR.

The field work of the Director is necessarily more or less desultory and largely of reconnaissance character, as it is impossible for him to obtain sufficient respite from administrative duties to undertake either systematic or areal work.

In July he visited Marthas Vineyard, Mass., to consult with Prof. N. S. Shaler in relation to his work in Rhode Island and to examine the drift deposits on the north shore of Marthas Vineyard. Numerous siliceous pebbles occur along the beach, that were transported in Pleistocene time from New England or farther north. The pebbles contain Cambrian fossils that are now known to occur only in the Cambrian rocks of Great Belle Island, Conception Bay, Newfoundland. A brief study was also made of the sand dunes on the southwestern coast of Rhode Island, and of tidal deposits on the same coast.

En route to the Northwest, in August, attention was given to observations on the general features of the country, from Williston, N. Dak., westward on the line of the Great Northern Railway. Notes were made on the geology and the possibilities of irrigation in the Missouri Valley, from Williston west to Milk River, Montana. Sufficient was learned to indicate that the control and use of the waters of the Missouri for irrigation requires the construction of extensive and elaborate works, and that, preliminary to this, first-class topographic maps should be made of much of the area of northeastern Montana and northwestern North Dakota.

In company with Messrs. W. H. Weed and F. B. Weeks, a trip was made into the Neihart district by the way of Great Falls, the return being by White Sulphur Springs and Townsend to Helena. The district had been surveyed and mapped by Mr. Weed, and the Director's attention was given chiefly to the examination of several areas of doubtful pre-Cambrian rocks. A brief reconnaissance was made about Helena and along the line of the railroad from Helena to Butte, with reference to entering upon the mapping of this region in 1896. At Butte the Director was met by Mr. Emmons, and together they examined the Butte district, in order to arrange for its geological survey in 1896, the special topographic map being completed at the time of the visit.

From Butte the trip to Spokane, Wash., was made in daytime, and notes were taken on the general geology along the line of the Northern Pacific Railway. As this region is entirely unmapped, even such a hurried glance will be of service in the future in planning work. With Messrs. Emmons and Weed, the Director next visited the Cœur d'Alene district of northern Idaho, stopping at Wallace, Burke, and Wardner. The mines of the district were found to occupy fissures in a great series of siliceous slates and quartzites of Cambrian age.

In September a reconnaissance was made, again in company with Messrs. Weed and Weeks, of the region about Columbia Falls, Mont., and to the north and east, on the line of the Great Northern Railway. The area examined included about 1,200 square miles, the rocks of which were found to be largely of middle and lower Cambrian age. The data secured in northern Idaho and northwestern Montana show that more than 20,000 square miles of the area between the crest of the Rockies and the one hundred and seventeenth meridian, and 47° 30′ and 49° north latitude, is underlain by the older Cambrian rocks. It will be necessary to map the Cœur d'Alene and Lake MacDonald districts with great care before any reliable data can be secured that will be of value in the further development of their mining industries and those of districts yet unknown that may be concealed in this great forest-covered area.

From the examinations made in northern Idaho and about Spokane, Wash., it appears best to start with a base line near Spokane, and thence push the work of mapping eastward across northern Idaho and northward up the Columbia River Valley to the British boundary.

In the office the study of the Cambrian faunas, which had been suspended in 1894, was resumed. All the time that could be spared from administrative duties and the consideration of the numerous scientific questions that arise from day to day in the course of the general work of the Survey was given to the completion of a monograph on fossil Medusæ and, during June, to the study of the Cambrian fossils from the Yellowstone National Park.

The Director had the assistance in the office work of the year of Dr. William F. Morsell, stenographer and general assistant, and Miss Jean F. Kaighn, confidential clerk.

DIVISION OF PALEONTOLOGY.

As in the preceding year, several of the paleontologists were engaged in securing paleontologic evidence in the field to assist the geologists in the determination of the various geologic formations, for the purposes both of mapping the distribution of the rocks and of determining their vertical range.

Stanton party.—Mr. T. W. Stanton cooperated with Mr. R. T. Hill in the study of the Cretaceous rocks of northern Texas. Fossils were collected from the section at Denison and at other important localities, including Preston, Gainesville, Decatur, Granbury, Comanche Peak, and Glen Rose. The exposures about Fort Worth were also examined. A long journey was then made westward and southwestward from Austin to Brackettville, which gave Mr. Stanton an excellent opportunity to study the development of the entire lower Cretaceous Comanche series and the region about Fredericksburg, which was the seat of Dr. Roemer's early studies. Collections were made at various localities in the area of the Brackettville and Nueces sheets.

A reconnaissance was also made by Mr. Stanton, in company with Mr. Vaughan, from Brackettville to Del Rio, and thence along the valley of the Rio Grande to Santa Tomas, the return journey being by way of Carrizo Springs and Uvalde to Brackettville. The section examined on this journey begins in the Washita division of the lower Cretaceous and extends through the upper Cretaceous, which has a great development here and includes a coal-bearing horizon. There is another workable coal deposit in the superjacent Eocene rocks. A reconnaissance was also made by Mr. Stanton to the Cretaceous coal field of San Carlos, in Presidio County.

The principal object of Mr. Stanton's work was to gain a definite personal acquaintance with the stratigraphy and local development of various areas of the Texas lower Cretaceous rocks, and to make as large a collection of fossils from them as possible, preparatory to undertaking a monographic study of the Cretaceous faunas. Mr. Hill has studied the Cretaceous formations of Texas for many years, and his and Mr. Stanton's data will afford the material for a thorough and exhaustive report upon the Cretaceous rocks and faunas of the Southwest.

On returning from the field, Mr. Stanton began the study of the lower Cretaceous fossils of the Texas region. This was continued at intervals to the close of the year, all the collections being properly recorded and numbered, a considerable proportion of them identified, and preliminary lists furnished to geologists for immediate use. Nearly all the species of cephalopods were critically studied and described. He also continued the routine work of identifying fossils and reporting upon them for members and correspondents of the Survey and National Museum, and during the winter the card catalogue of type specimens of the Mesozoic invertebrate fossils of the National Museum was revised and brought up to date, with the assistance of Messrs. Charles Schuchert and William Whipple, of the Museum staff. He also prepared and submitted to the Director for his use a card catalogue of Mesozoic formation names that have been proposed in the United States and Canada, with brief definitions and synonymy. Considerable time was given also to the preparation of a paper on The Faunal Relations of the Eocene and upper Cretaceous on the Pacific Coast, which appears in Part I of this Annual Report.

Hyatt party.—Prof. Alpheus Hyatt was employed at intervals during the year in the revision of the manuscript of a treatise on the Cretaceous fossils collected in the Tucumcari region of New Mexico. The collections, together with descriptions and sections of the geology of the region, were subsequently forwarded to Messrs. T. W. Stanton and R. T. Hill. At the request of the latter, Professor Hyatt also spent considerable time upon the revision of the remarkable and characteristic Cretaceous group of Ammonitinæ, hitherto represented by the genera Buchiceras, Engonoceras, etc. This work was also laid aside for a time in order that Professor Hyatt might make a report upon a collection of fossils secured by Dr. Dall in Alaska, and this is appended to Dr. Dall's paper in Part I of this Annual Report.

Dall party.—The report of Dr. W. H. Dall's field work is given on a previous page, in connection with the work of Dr. Becker in Alaska. His assistant, Mr. Frank Burns, was at work in Texas, under instructions from Mr. Hill, to whom he had been detailed for the summer. In June, 1896, Mr. Burns was in the field near Suffolk, Va., collecting Tertiary fossils.

Apart from the usual routine, Dr. Dall's office work consisted in the preparation of the report, mentioned above, upon the coal resources of Alaska, which comprises a summary of all that is known in regard to these deposits and a comparison of the coals with coals from other parts of the world. To this was added a summary of what is known of the paleontology of Alaska, in the preparation of which Dr. Dall received contributions from Messrs. Hyatt, Knowlton, and Schuchert.

Dr. Dall next examined and made a preliminary report upon a large collection of Tertiary fossils obtained by Mr. J. S. Diller in Oregon and California, after which he prepared for the Director a correlation table, with proper references, showing the subdivisions of the Tertiary in the various regions of the United States—Pacific region, Central basin, Gulf region, and Atlantic Coast—and their equivalents, so far as known, and, in the case of the larger groups, their European equivalents also. Such time as remained was employed in the study of the Tertiary fossils of the southeastern United States, in continuation of the work which has occupied much of his time for several years.

Ward party.—Prof. Lester F. Ward was engaged in an investigation of the distribution of the fossil-plant remains of the lower Cretaceous and the Jurassic of the West. He first examined the Cretaceous rim on the east side of the Black Hills, where he secured some fine specimens of fossil cycads. His next investigations were in the vicinity of Great Falls, Mont., whence he visited the coal-bearing beds lying between the Highwood and Little Belt mountains, making large collections of fossils from the various coal openings.

On the 6th of August he joined Mr. Diller's party at Roseburg, Oreg. It was there arranged that he should be accompanied and assisted in subsequent journeyings and investigations by Mr. James Storrs, until that time a field assistant with Mr. Diller. With Mr. Storrs, Professor Ward proceeded to Ono, Cal., and visited the region about that place and Horsetown, making collections in the Horsetown and Knoxville beds. Other collections were made on the banks of Cold Fork of Cottonwood Creek, some miles farther south, and in the vicinity of Lowreys and Elder Creek, and from the plant-bearing slate at the Banner mine, 5 miles east of Oroville. Professor Ward then joined Mr. H. W. Turner's party at Merced Falls. A careful search was made in the Mariposa slates for plant remains, but, owing to the fact that these slates are very extensively metamorphosed, only a few traces of such remains were found. He next studied the *Sequoia gigantea* on the Mariposa Big Tree grant. This genus formerly ranged over the entire continent eastward as far as the Potomac River, but it is now confined to two species found only on the Sierras and the Coast Range of California. It occurs abundantly in fossil form from the lower Cretaceous to the Pleistocene.

Professor Ward's collections and studies will be of great service in the correlation of the Cretaceous and Tertiary strata of the Northwest, especially of those beds from which all other forms of life are absent.

On returning from the field in Colorado, Professor Ward unpacked the collections made and prepared them for study. He then resumed and continued the detailed study of the cycadean trunks from the lower Cretaceous of Maryland and the Black Hills, and some time was given to the reading and correcting of proofs of the paper in the Director's Sixteenth Annual Report entitled, Some Analogies in the Lower Cretaceous of Europe and America.

Prof. William M. Fontaine, who was engaged at intervals in Survey work, completed a report on the lower Cretaceous flora of the Hay Creek coal field (Black Hills, Wyoming), and transmitted it, with the collections, in March. He then took up for study the lower Cretaceous fossils collected by Professor Ward in Montana.

Professor Ward was assisted in the office by Miss L. M. Schmidt, who continued, under his direction, the preparation of a bibliography of paleobotany.

Knowlton party.—Prof. F. H. Knowlton's field work was restricted in the fiscal year 1895–96 to the latter part of June, when he started for Colorado to collect fossil plants from the various coal-bearing series in the vicinity of Denver. The work was hardly initiated before the fiscal year closed.

In the office a preliminary study was made of the fossil flora of the Yellowstone National Park, and a report submitted in September, and this was followed by an exhaustive study of the same fauna, which was finished in April. The final report embraces 359 pages of manuscript and 45 quarto plates, and will constitute a part of the monograpn on the park. This study is of much geologic interest and value, as it will serve to fix very definitely the age of the post-Laramie volcanic eruptions of the park. By the age of the plants it was found that the later, acid series of breccias is of Eocene (Fort Union) age, and the younger, basic breccias of Miocene (Auriferous Gravels) age. An intermediate age was also determined by the presence of some 30 species of flora which are regarded as of lower Miocene age.

Marsh party.—Early in the year Professor Marsh spent considerable time in the preparation of a chapter on the vertebrate fossils of the Denver region, for incorporation in the monograph on the Denver Basin, now in press (Monograph XXVII). This memoir will be illustrated by nearly 100 figures of characteristic vertebrate fossils, and in it is a summary of the characteristic fossils found in each geologic horizon. He continued his study of the vertebrate collections made by him within the period from 1882 to 1890, and, finding it necessary to examine the collections of dinosaurian remains in the European museums before completing his monograph, he visited Europe and inspected collections in the British Museum and in the museums of Holland, Brussels, Stuttgart, and Paris. On his return to America he resumed work on the monograph on the Sauropoda, which is now nearly completed

DIVISION OF CHEMISTRY.

During the fiscal year 1895–96 the work of the Division of Chemistry was continued under the charge of Prof. F. W. Clarke, who was assisted by Dr. W. F. Hillebrand, Dr. H. N. Stokes, and Mr. George Steiger, with some cooperation from Prof. Charles E. Munroe, of the Columbian University, and Prof. L. V. Pirsson, of Yale. During the first half of the year Professor Clarke was absent from Washington almost continuously, in charge of the exhibits of the Department of the Interior at the Cotton States and International Exposition, at Atlanta. After his return to Washington he was largely occupied with administrative duties.

Apart from the routine work, little was done during the year. The purely scientific researches, which are so desirable, must give way to the analyses which are more immediately in demand. Still, Dr. Stokes made some progress with his investigations relative to the phosphoric acids, and will soon have some material ready for publication.

The number of routine analyses completed during the year is 395, and the work is now well up to date. Among the analyses reported were some large and important series, such as 32 rocks from the Gold Belt of California, 30 rocks from Montana, 12 rocks from Alaska, 12 complicated ores from Aspen, Colo., 21 limestones and dolomites from Colorado, 13 borings from an artesian well at Key West, Fla., and 10 slates from Vermont and New York. There were also 85 coals, some of them from Oregon, some from Alaska, some from West Virginia, and some from Texas.

DIVISION OF HYDROGRAPHY.

This division was continued in charge of Mr. Frederick H. Newell, whose permanent assistants were Messrs. Arthur P. Davis and Cyrus C. Babb.

During the past year the work of this division has expanded under the larger opportunities afforded by an increased appropriation. Field work has been carried on in a manner similar to that of the preceding year, but a larger number of streams have been measured and a broader area has been covered by the investigations of underground waters and artesian wells. The field operations have been gradually differentiated into three classes of work, the first, of a somewhat strictly engineering character, having to do with the measurement of the surface streams and the consideration of water supply through storage of flood waters in reservoirs; the second, of a geologic nature, consisting of detailed examination of the underground structure and permeability of the water-bearing rocks, and the third consisting of general reconnaissance for obtaining information as to the methods of utilizing the water supply for power, irrigation, or domestic purposes. Each of these three classes of investigation requires for successful results men specially trained. In addition to the permanent assistants, Messrs. Davis and Babb, the division has employed a number of skilled resident hydrographers, enumerated in a more detailed description given below. In the conduct of the second class of work, the investigation of the underground water supply, Mr. G. K. Gilbert has examined and reported upon a portion of the Great Plains, and field work with a similar object in view has also been carried on by Mr. N. H. Darton in North Dakota and South Dakota and by Mr. Robert T. Hill in Texas, as previously stated. The third class of investigation, consisting of general reconnaissance and study of methods of utilizing the water resources, has been carried on by Mr. Newell in connection with the office work, which has consisted largely of the preparation of reports and attention to the constantly increasing correspondence.

In the following description of operations in various parts of the country an arrangement is adopted based in a broad way upon the physical conditions of the country and the methods which have grown up in keeping the office records. First comes the humid region—the New England and Northeastern States, those of the middle Atlantic slope and of the south Atlantic slope, and the States and portions of States lying at the head waters of the Ohio and upper Mississippi. In the next category are the States lying mainly within what is known as the subhumid region, these being usually described in order from north to south, beginning with North Dakota and ending with Texas. Finally come the States of the arid region, these being discussed usually in alphabetic order, beginning with Arizona and ending with Wyoming.

HUMID REGION.

Northeastern States.—An attempt has been made during the past year to bring together all available information concerning the water resources of this part of the country preliminary to making detailed measurements at important points. Although here there has been the greatest development of manufacturing interests dependent upon water power, there appears to be relatively a small amount of data, and this is widely scattered in the hands of individuals and corporations.

It is believed that by persistent effort valuable information can be obtained, which, when supplemented by field work, will exhibit not only the value of the water powers but also bring to public attention many unutilized resources.

Middle Atlantic Slope.—Within the Potomac basin, lying in the States of Maryland, Virginia, and West Virginia, a number of river stations have been maintained throughout the year. The work at these points was transferred by Mr. Babb to Prof. D. C. Humphreys, of Lexington, Va., who has also established stations upon the James River and upon tributaries of the upper Ohio in West Virginia, and has made a general reconnaissance and study of available water powers.

South Atlantic Slope.—In North Carolina and South Carolina the river work has been placed in the charge of Prof. J. A. Holmes, who, through the assistance of Mr. J. V. Lewis and later of Mr. E. W. Myers, has carried on work at a number of localities upon the Roanoke, Cape Fear, Yadkin, Catawba, French Broad, and other rivers.

In Georgia, systematic measurements of the Chattahoochee River near Atlanta and of the Ocmulgee River near Macon were begun by Mr. Cyrus C. Babb, and later were placed under the charge of Mr. B. M. Hall, hydraulic engineer, of Atlanta, Ga. A general reconnaissance has been undertaken by the latter and considerable information obtained, with the intention ultimately of bringing together the scattered data and preparing a report upon the water resources of portions of Georgia, Alabama, and Florida.

Upper Ohio and Mississippi.—The fields of operation of Professor Humphreys and Professor Holmes extend over the divide of the Alleghany Mountains, a number of streams tributary to the Ohio being measured or examined for preliminary reports upon the water power. Farther westward, within the Mississippi Valley proper, the chief matter of public interest regarding water supply is the possibility of obtaining it in sufficient quantity and of suitable quality for domestic purposes. As a consequence, a knowledge of the possibilities of obtaining wells is of prime importance. Toward satisfying the demands for knowledge, Mr. Frank Leverett has been employed in the preparation of a report upon the water supply of Illinois. Data for his paper are based largely upon the results of studies of glacial phenomena, made by him during several years under the direction of Prof. T. C. Chamberlin. His conclusions, which relate not only to Illinois but to a portion of Indiana, may be found in Part II of this Annual Report, and material has been obtained for a further discussion of the subject of water supply from wells of portions of Indiana and Ohio lying farther to the east.

SUBHUMID REGION.

North Dakota and South Dakota.—In these States Mr. N. H. Darton has made a reconnaissance of the artesian conditions, mainly of the James River Valley, being assisted in part by Maj. Fred F. B. Coffin. The results of this work may also be found in Part II of this Annual Report.

Nebraska.—The measurement of the streams of this State has been carried on by Prof. O. V. P. Stout, of the State University, at Lincoln. He has brought about a general cooperation in such work, both with the State board of irrigation and with the university, resulting in greater efficiency and economy in obtaining results of public value. Prof. Erwin N. Barbour has collected a large amount of information relating to the wells of this State, but the funds available have not been sufficient to complete the preparation of this material for publication.

Kansas.—Arrangements have been made with the Kansas State board of irrigation, through the secretary, Mr. W. B. Sutton, by which the civil engineer of the board, Mr. W. G. Russell, has taken charge of many of the river stations established by this Survey. The observers at most of these points are paid out of the State appropriation. In addition to this work of cooperation, Prof. E. C. Murphy, of the University of Kansas, has had charge of river stations in the eastern part of the State, and Prof. O. P. Hood, of the State Agricultural College, has made measurements at a point not far from the experiment station.

Texas.—The work of Mr. R. T. Hill in Texas is described on an earlier page. At his suggestion Mr. Cyrus C. Babb has made a reconnaissance of some of the spring-fed streams, measuring these at the time of his visit.

ARID REGION.

Arizona.—A detailed examination of the water resources of a portion of the Salt River and Gila valleys has been made by Mr. Arthur P. Davis, assisted by Mr. Cyrus C. Babb and Mr. J. B. Lippincott. The primary object was to ascertain the water supply for the irrigation of agricultural lands of the Gila River Indian Reservation, the amount of $3,500 having been allotted from the Indian funds for this purpose. As essential to this work, Mr. Davis obtained data concerning the water supply of this part of Arizona, with the intention of preparing a paper upon the general subject in addition to his detailed report for the Indian Bureau. Systematic measurements have been made of the Gila River above Florence, and figures have been obtained regarding the flow of the Salt and Verde rivers. In addition, a few measurements have been made of the Colorado River at Yuma.

California.—The river measurements in this State have been continued by Mr. J. B. Lippincott, assisted by Mr. John A. Vogleson, field work being conducted mainly in the San Joaquin Valley, and later, on account of the expense of railroad transportation, concentrated toward the southern portion of the State. Mr. Lippincott prepared a detailed report upon the water supply of the areas examined, which has been printed as a portion of Bulletin No. 140.

Colorado.—The cooperation of the State engineer of Colorado has been continued through the assistance given by Mr. F. Cogswell, deputy State engineer. A number of river stations have been established and maintained in the southern and western part of the State, the expenses being paid by this Survey, while other river stations, located chiefly in the northern part of the State and accessible from Denver, have been supported mainly by the State engineer. The principal exception is the series of measurements made on Cache la Poudre River by Prof. L. G. Carpenter, of the Agricultural College. In the Arkansas basin, Mr. G. K. Gilbert continued his geologic field work, having especial reference to the underground water supply. The results obtained by him have had immediate practical benefit, as shown by the confidence with which deep drilling has been undertaken at various points.

Idaho.—Mr. Gerald F. Sherman has had charge of the river stations in this State during the greater part of the year, being succeeded upon leaving the State by Mr. Lyman B. Kendall, formerly an assistant hydrographer and later a topographer of this Survey. He is working in cooperation with the State engineer and is obtaining data not only of general value but of special application to the problems of this region.

Montana—The active oversight of the field measurements in this State has been continued by Prof. A. M. Ryon, of the State Agricultural College. His operations have necessarily been confined to portions of the State easily accessible from Bozeman and within the drainage basin of tributaries of the Missouri.

Nevada.—During the early part of the year measurements were made at various points on the Truckee, Carson, Walker, and Humboldt rivers. During the winter a number of these stations were discontinued, and on removal of the resident engineer, Mr. L. H. Taylor, to Battle Mountain, Nev., operations were concentrated at points along the Humboldt River.

New Mexico.—The greater part of the examinations in this State have been along the Rio Grande, this stream being of interstate and international importance as regards questions of water supply. Besides the systematic measurements at designated points, Mr. P. E. Harroun has made a study of the conditions of a portion of the Rio Grande Valley above Albuquerque, his report being embodied in Bulletin No. 140.

Oregon.—The investigation of the water supply of the extreme eastern end of this State has been in the charge of Mr. G. F. Sherman, and later of Mr. Lyman B. Kendall, as previously mentioned under the head of Idaho. A reconnaissance of a few points on the Umatilla River was made by Mr. Arthur P. Davis, but it was not found practicable to reestablish river stations.

Utah.—The rivers of the northern part of this State have been systematically measured by Prof. Samuel Fortier, of Logan, Utah, who has also made a thorough study of the question of the return of seepage water, especially along the Ogden River. This work is of the utmost importance to the development of the agricultural resources of the State.

Washington.—The observations of fluctuations of height of water in the Yakima River and some of its tributaries have been continued during a large part of the year, but owing to the difficulty of securing systematic measurements of discharge, work has to a large extent been discontinued. The water supply of this part of the State is so large that public interest has not been manifested in the continuation of such investigations.

Wyoming.—Field work has been continued under the direction of Prof. Elwood Mead, State engineer, assisted by Mr. W. M. Gilcrest. The river stations are mainly upon the North Platte and its tributary, the Laramie River. In the northern part of the State, near Sheridan, Mr. Gillette has made computations of the water supply in Goose Creek.

LIST OF RIVERS MEASURED.

The following list gives, by drainage basins, the localities at which systematic measurements of rivers have been made. The list is arranged in a general geographic order, beginning with the drainage basins of the Atlantic Slope and ending with those of southern California. At localities marked with an asterisk the work has been carried on, in whole or in part, at the expense of individuals or States.

List of rivers systematically measured in 1895–96.

River.	State.
Potomac basin:	
South branch of Shenandoah River at Springfield.	West Virginia.
Potomac River at Cumberland	Maryland.
Potomac River at Great Cacapon	West Virginia.
North and South rivers at Port Republic	Virginia.
Shenandoah River at Millville	West Virginia.
Potomac River at Point of Rocks	Maryland.
Potomac River at Chain Bridge	District of Columbia.
James River basin:	
North River at Glasgow	Virginia.
James River at Buchanan	Do.

List of rivers systematically measured in 1895–96—Continued.

River.	State.
Eastern North Carolina rivers:	
Dan and Staunton rivers at Clarksville	Virginia.
Cape Fear River at Fayetteville	North Carolina.
Yadkin River at Holtsburg	Do.
Catawba River at Fort Mill	Do.
Georgia rivers:	
Ocmulgee River at Macon	Georgia.
Chattahoochee River at Oakdale	Do.
Ohio River tributaries:	
Greenbrier River at Alderson	West Virginia.
New River at Fayette	Do.
French Broad River at Asheville	North Carolina.
Texas rivers (reconnaissance):	
Colorado River at Austin	Texas.
San Marcos Spring	Do.
Comal River	Do.
San Antonio and San Pedro Springs	Do.
Sabinal River	Do.
Leona River	Do.
San Moras Spring	Do.
San Felipe Springs	Do.
Upper Missouri basin:	
West Gallatin River at Salesville	Montana.
Middle Creek above Bozeman	Do.
Gallatin River at Logan	Do.
Madison River at Three Forks	Do.
Jefferson River at Sappington	Do.
Missouri River at Townsend	Do.
Big Goose Creek at Sheridan	Wyoming.
Platte basin:	
Laramie River at Woods Landing	Wyoming.
Laramie River at Uva	Do.
North Platte River at Orin	Do.
North Platte River at North Platte	Nebraska.
South Platte River at Deansbury*	Colorado.
South Platte River at Denver*	Do.
Bear Creek at Morrison*	Do.
South Boulder Creek at Marshall*	Do.
Boulder Creek at Boulder*	Do.
St. Vrain Creek at Lyons*	Do.
North Loup River at St. Paul	Nebraska.
Middle Loup River at St. Paul	Do.
Loup River at Columbus	Do.

List of rivers systematically measured in 1895–96—Continued

River.	State.
Platte basin—Continued.	
Platte River at Columbus	Nebraska.
Salt Creek at Lincoln	Do.
Kansas basin:	
North Fork of Republican River at Benkelman	Nebraska.
South Fork of Republican River at Benkelman	Do.
Frenchman River at Wauneta	Do.
Frenchman River at Palisade	Do.
Republican River at Junction City	Kansas.
Solomon River at Beloit	Do.
Saline River at Beverly	Do.
Smoky Hill River at Ellsworth	Do.
Blue River at Manhattan	Do.
Kansas River at Lawrence	Do.
Arkansas basin:	
Arkansas River at Granite	Colorado.
Arkansas River at Salida	Do.
Arkansas River at Canyon	Do.
Arkansas River at Pueblo	Do.
Arkansas River at La Junta	Do.
Arkansas River at Holly	Do.
Arkansas River at Hutchinson	Do.
Verdigris River at Liberty	Kansas.
Neosho River at Iola	Do.
Medicine River at Kiowa	Do.
Cimarron River at Arkalon	Do.
Mora River at Watrous	New Mexico.
Rio Grande basin:	
Rio Grande at Del Norte	New Mexico.
Rio Grande at Alamosa	Do.
Rio Grande at Embudo	Do.
Chama River at Abiquiu	Do.
Rio Grande at Rio Grande	Do.
Rio Grande at San Marcial	Do.
Rio Grande at El Paso	Texas.
Colorado basin:	
Grand River at Grand Junction	Colorado.
Uncompahgre River at Fort Crawford	Do.
Gunnison River Fort Crawford	Do.
Grand River at Grand Junction	Do.
Dolores River at Dolores	Do.
San Miguel River at Seymour	Do.
San Juan River at Arboles	Do.

List of rivers systematically measured in 1895-96—Continued.

River.	State.
Colorado basin—Continued.	
Piedra River at Arboles	Colorado.
Animas River at Durango	Do.
Green River at Green River	Wyoming.
White River at White River	Colorado.
Green River at Blake	Utah.
Gila River at Buttes	Arizona.
Colorado River at Yuma	Do.
Interior basin:	
Truckee River at Tahoe	Nevada.
Carson River at Empire	Do.
Walker River at Nordyke	Do.
Humboldt River at Elko	Do.
Humboldt River at Golconda	Do.
Humboldt River at Oreana	Do.
Bear River at Battle Creek	Idaho.
Bear River at Collinson	Utah.
Ogden River at Ogden	Do.
Weber River at Uinta	Do.
Provo River at Provo	Do.
Columbia basin:	
Boise River at Boise	Idaho.
Boise River at Caldwell	Do.
Payette River at Payette	Do.
Weiser River at Weiser	Do.
Bureau River at Grand View*	Do.
Snake River at Montgomery Ferry	Do.
Owyhee River at Nyssa	Oregon.
Malheur River at Vale	Do.
Naches River at North Yakima	Washington.
Yakima River at Union Gap	Do.
Topinish Creek at Topinish	Do.
Satas River at Satas	Do.
Takima River at Kiona	Do.
Sacramento and San Joaquin basin:	
Sacramento River at Red Bluff	California.
Port Tejon Creek *	Do.
Salt and San Emidio Creeks *	Do.
Pastoria Creek *	Do.
Tunis Creek *	Do.
Tejon House Creek at Tejon House	Do.
Rancheria Creek *	Do.
Caliente Creek *	Do.

List of rivers systematically measured in 1895–96—Continued.

River.	State.
Sacramento and San Joaquin basin—Continued.	
Kern River above Bakersfield	California.
Kings River at Kingsburg	Do.
Kings River at Red Mountain	Do.
San Joaquin River at Herndon	Do.
Fresno River	Do.
Merced River	Do.
Tuolumne River at Modesto	Do.
Tuolumne River at Lagrange	Do.
Stanislaus River at Oakdale	Do.
Mokelumne River at Lodi	Do.
Southern California streams:	
San Gabriel River at Azusa	California.
Mohave River	Do.
Whitewater River *	Do.
Santa Ana River *	Do.
San Luis Rey River	Do.
Sweetwater River	Do.

REPORTS PREPARED.

The results of the field work of the Division of Hydrography for the calendar year 1895 have been printed as Bulletin No. 140. This gives, without illustrations, the observations, measurements, and results of computations, the material being printed at the earliest opportunity in order to make the data available for general use. The papers by Messrs. G. K. Gilbert, N. H. Darton, and Frank Leverett have been mentioned. These relate respectively to the underground water supply of eastern Colorado, the Dakotas, and Illinois. Mr. R. T. Hill is preparing a paper on the water supply of Texas. In addition to these, preparations have been made for publishing a series of short reports giving the results of stream measurements, the ways of utilizing the water resources for power and irrigation, the conditions governing the occurrence of water underground, the methods of obtaining this by pumps or other devices, and also of storing and applying it to agricultural uses. A number of these papers are in preparation and the data for others are being obtained.

DIVISION OF MINERAL RESOURCES.

The work of the Division of Mineral Resources, under the charge of Dr. David T. Day, consisted mainly, during the fiscal year just closed, in the correspondence necessary to the gathering and compilation of the statistical data for the calendar year 1895 and in the preparation of the report embodying those data, which is published as Part III of this Annual Report.

In pursuance of the authority conferred by Congress for the immediate and separate publication of the various chapters of the report on mineral resources, several of the chapters of the report for the year 1895 are now in the hands of the printer, and in addition a tabular statement of the totals of the several mineral products was issued before the close of the fiscal year. Besides the work involved in the collection and compilation of statistical data, considerable time was given during the year to the preparation of replies to demands for technical information touching the conditions of occurrence and uses of the various useful minerals found in the United States. Two weeks of the spring of 1896 were occupied by Dr. Day in an inspection of certain new localities in northern Florida and southern Georgia where fuller's earth has become an important article of shipment within the last year. The examination was extended into other parts of Florida, and some valuable deposits were discovered in the neighborhood of Ocala and Tampa. Similar deposits in North Carolina and Virginia were also examined. Comparative tests were made to establish the relative values of these several American products and the standard English fuller's earth. The results of the inquiry are embodied in Part III of this Annual Report. A sample from a deposit in South Dakota was tested along with the other samples, and will be referred to in the same connection.

Dr. Day was assisted in the work of the division throughout the year by Messrs. E. W. Parker, W. A. Raborg, and Jefferson Middleton, and for longer or shorter periods by a corps of statistical experts, employed temporarily.

The total value of the mineral products of the United States for the year 1895 increased nearly $100,000,000 beyond that of 1894, or from $527,144,381 to $622,122,708. This increase is a long step toward recovery from the depression to which the mineral industry, like all others, has been subjected. The total value is slightly less than the greatest ever known, which was over $648,000,000, in 1892. In terms of quantities produced, instead of value received, 1895 is greatest. In other words, prices are lower.

If one considers the total values recorded in these reports since 1880, the increase from $369,319,000 to $622,122,708 is significant, and while it is impossible to select any year as a normal one from which to note increases and decreases, and to record the permanent increase in the mining industry, still the average for these sixteen years gives a fair approximation to what our normal mineral product should have been halfway between these dates, or in 1888. Comparing this computed normal product with the actual products, one sees that the average yearly gain due to the general growth of the industry should be about $25,000,000, or the product of 1895 should have been $670,000,000. The great products of 1892 and 1895 show the ease with which the mines can respond to any unusual demand. They show that the capacity is significantly greater than the ability to market the product; in fact, it is difficult to confine the large capacity to actual requirements. With very slight encouragement the product takes a phenomenal stride. In 1892 and 1895 the product most difficult to hold in check has been iron. This product easily controls the variations in the total value, either by the quantity produced or by the changes in price. While the coal product is so great as to make a significant factor in the total value, it is much steadier, and this in spite of the extra demand for it in order to produce any extra supply of iron. The increased output of iron in 1895 was necessary because of the great retrenchment in 1894. The railroads ordered as little iron as possible in that year, but ordered freely in 1895, to take advantage of prices while they were still low but advancing. This advance was a marked industrial feature of the year, and continued till September.

The United States shared in the general increase in gold production, the increase being shown in nearly all the gold-producing States, but coming principally from Cripple Creek and other new camps in Colorado. The gain in the quantity of petroleum, but especially the phenomenal increase in its price, was one of the great features of the year.

METALS.

Iron and steel.—The declining tendency in production in 1894, noted in the previous report, was changed in 1895 to one of the most remarkable increases in the production of pig iron known in the history of the industry in the United States, it being from 6,657,388 long tons in 1894 to 9,446,308 tons in 1895, or nearly 42 per cent. This is the largest product ever attained in this country, the nearest approach to it being in 1890, when the output was 9,202,703 tons. The value also increased from $65,007,247 in 1894 to $105,198,550 in 1895, or from $9.76 to $11.14 per ton. The value per ton in 1890, the year of nearest approach to 1895, was $16.43.

Iron ores.—The production of iron ores in 1895 was 15,957,614 long tons, valued at $18,219,684, as compared with 11,879,679 long tons, with a value of $13,577,325, in 1894. Twenty-five States and Territories contributed to make up this total in 1895, an amount exceeded only by the outputs of the years 1890 and 1892. A comparison between the quantities reported indicates an increased production in 1895 of 34 33 per cent on the total for 1894, and with but six exceptions all of the iron ore producing States participated in this advance. Owing to contracts that were made in advance, the average price per ton of iron ore was not so high in 1895 as in years previous to 1894, but the value per ton in 1896 bids fair to be much higher.

Steel.—The total value of all forms of steel in the United States in 1895 was $117,500,000. Of this total $31,640,000 was for steel rails and $85,860,000 for other forms of steel. The value of the steel other than rails is that for the raw and intermediate forms, not for the most finished forms.

Limestone for iron flux.—This product naturally followed the course of the iron industry and showed a large increase, or from 3,698,550 long tons in 1894, worth $1,849,275, to 5,247,949 tons in 1895, worth $2,623,974.

Gold and silver.—The steady increase in the gold product of the United States since 1892 was kept up during 1895, increasing from 1,910,816 ounces in 1894 to 2,254,760 ounces in 1895. The value of these products was $39,500,000 and $46,610,000, respectively. The production of silver also increased from 49,501,122 ounces in 1894 to 55,727,000 ounces in 1895, with coining values respectively of $64,000,000 and $72,051,000.

Copper.—Copper production followed the upper tendency of the other metals and increased from 354,188,374 pounds in 1894 to 380,613,404 pounds in 1895. The value increased from $33,141,142 in 1894 to $38,682,347 in 1895. All of the foregoing was from domestic ores. In addition, 10,678,434 pounds in 1894 and 12,026,560 pounds in 1895 were produced from imported pyrites.

Lead.—The production of lead increased from 159,331 short tons in 1894 to 161,440 in 1895. The value in 1894 was $9,942,254 and $10,655,040 in 1895.

Zinc.—The rapidly increasing product of this metal, which was checked in 1893 and 1894, was resumed in 1895, when 89,686 short tons were produced, worth $6,278,020, as compared with 75,328 short tons in 1894, worth $5,288,026.

Quicksilver.—The increase in production noted in 1894 was continued in 1895, the figures being 36,104 flasks in 1895, as compared with 30,416 flasks in 1894. The value of this product increased from $934,000 in 1894 to $1,337,131 in 1895.

Manganese.—The production of manganese ore increased from 6,308 long tons in 1894 to 9,547 in 1895. This increase came mostly from two States, Arkansas and Georgia, these alone producing more than the entire product of 1894. The Virginia product continued to decline. The manganiferous iron-ore product declined quite markedly in 1895, or from 205,488 long tons, valued at $408,597, in 1894, to 125,729 long tons, valued at $233,988, in 1895. The manganiferous zinc ores increased in quantity and value in 1895.

Aluminum.—Aluminum continued its increased product in 1895, the quantity rising from 550,000 pounds in 1894 to 920,000 pounds in 1895. The value increased from $316,250 in 1894 to $464,600 in 1895.

Antimony.—The antimony product increased from 200 short tons in 1894 to 450 tons in 1895, and the value from $36,000 in 1894 to $68,000 in 1895. The product was from California, Nevada, and Montana. This includes the metal produced from imported ores, there having been but 86 tons of domestic ore raised during the year.

Nickel.—The product of nickel in the United States in 1895 increased slightly over that of 1894, or from 9,616 pounds to 10,302 pounds, while the value decreased from $3,269 in 1894 to $3,091 in 1895. The Nevada and Oregon mines are still nonproducers. There are vague reports of new deposits in Minnesota, and two companies have been organized to develop them.

Tin.—No tin was produced in the United States in 1895.

Platinum.—The platinum product, all of which comes from the Pacific Coast, continues small, though there was a slight increase in the product—from 100 ounces, worth $600, in 1894 to 150 ounces, worth $900, in 1895.

FUELS.

Coal.—The total product of coal of all kinds in 1895 was 172,426,366 long tons, or 193,117,530 short tons, compared to 152,447,791 long tons, or 170,741,526 short tons, in 1894, an increase of 22,376,004 long tons, or 25,061,124 short tons, or 13 per cent. The value of the product increased from $186,141,564 to $197,769,043, a gain of $11,627,479, or about 6 per cent, showing that the percentage of increase in value was less than half of that of the increase in product. The product in 1895 was made up of 51,785,122 long tons of Pennsylvania anthracite (against 46,358,144 long tons in 1894), valued at $82,019,272, and 120,641,244 long tons of bituminous coal (against 106,089,647 long tons in 1894), valued at $115,749,771. The bituminous product includes scattering lots of anthracite from Colorado and New Mexico.

The year was marked by a production considerably in excess of the market demands, and values were much reduced in consequence. The average price obtained for the anthracite coal marketed was $1.72 per long ton at the mines, against

$1.85 in 1894 and $1.94 in 1893. In arriving at this average price the amount of coal consumed at the collieries is not considered. This factor consists of culm or slack which would otherwise be thrown on the dump or wasted. In determining the value of bituminous coal, all the coal mined and sold or used is included. The average price for this product shows a decline from 91 cents per short ton in 1894 to 86 cents in 1895. This decline in value was general throughout the United States, there being three or four comparatively unimportant States where the value was larger in proportion in 1895 than in 1894.

Petroleum.—The most notable features in connection with the production of crude petroleum in 1895 are: (1) The notable increase in production, especially in Ohio, Indiana, and California; (2) the decrease in stocks; (3) the rise in prices, and (4) the extension southward of the profitable producing districts in the Appalachian Range.

Briefly summarized, the facts regarding these four features of 1895 are as follows:

1. The production of petroleum in the United States increased from 49,344,516 barrels in 1894 to 52,983,526 barrels in 1895, most of the important producing districts sharing in this increase. The production of Pennsylvania increased from 18,077,559 barrels in 1894 to 18,231,442 barrels in 1895, an increase of 153,883 barrels, or 0.85 of 1 per cent; of Ohio from 16,792,154 in 1894 to 19,545,233 barrels in 1895, an increase of 2,753,079 barrels, or 16.4 per cent. This increase in Ohio was fairly distributed throughout the two important producing districts. The production of Indiana increased from 3,688,666 barrels in 1894 to 4,386,132 barrels in 1895, an increase of 697,466 barrels, or nearly 19 per cent, while the production of California, owing to the new discoveries at Los Angeles, increased from 705,969 barrels in 1894 to 1,208,482 barrels in 1895, an increase of 71 per cent, the largest percentage increase of any of the States.

2. The stocks of crude petroleum in the Appalachian oil field at the close of 1895 were 5,344,784 barrels, as compared with 6,499,880 barrels at the close of 1894. The largest stocks at the close of any one month in 1895 were 5,859,348 barrels

in January, as compared with 11,755,219 barrels, the largest stocks in 1894, which were also at the close of January. The smallest stocks at the close of any one month in 1895 were those of June, the stocks being 4,275,506 barrels, while the smallest stocks at the close of any one month in 1894 were those of December, as noted above. The average stocks at the close of each month in 1895 were 4,879,770 barrels.

3. The average value of certificate oil in the Pennsylvania field in 1895 was $\$1.35\frac{7}{8}$, as compared with $83\frac{7}{8}$ cents in 1894. This is the highest average price since 1877. The highest average price during any one month in 1895 was $1.79, in April; the lowest, 99 cents, in January. In the Lima field the average price advanced from 48 cents a barrel in 1894 to $71\frac{3}{4}$ cents in 1895. The total value of the 49,344,516 barrels produced in the United States in 1894 was $35,522,095, or nearly 72 cents a barrel, while the total value of the 52,983,526 barrels produced in 1895 was $57,691,279, or about $1.09.

Coke.—The total product of coke in the United States in 1895 was 13,333,741 short tons, as compared with 9,203,632 short tons in 1894. These two amounts represent the largest and smallest product of coke in recent years. The fluctuation was caused by the decline and rise of the pig-iron product, in the manufacture of which almost the entire coke output is consumed. The production of coke-smelted iron, or of iron smelted with a mixture of coke and anthracite, increased from 6,314,891 long tons in 1894 to 9,164,365 tons in 1895.

Natural gas.—This is one of the few important mineral products which showed a decline in value in 1895. The value decreased from $13,954,400 in 1894 to $13,006,650 in 1895. Among the notable features may be mentioned:

1. The decreasing pressure in all the natural-gas fields, but greatest in Pennsylvania.

2. Resulting from the above: A large falling off in the product of gas per well, which has led to a great increase in the number of wells, so as to maintain the supply.

3. The life of each well has been greatly shortened. In some cases in western Pennsylvania the average life of a well is only six months.

STRUCTURAL MATERIALS.

Stone.—The value of the total product of stone of all kinds decreased from $37,055,030 in 1894 to $34,688,816 in 1895. All varieties except sandstone participated in this decrease.

Soapstone.—The production of soapstone in the form of slabs, etc., in 1895 amounted to 21,495 short tons, valued at $266,495, which was a decrease from 1894, when the product was 23,141 tons, valued at $401,325. The production of fibrous talc also showed a slight decrease, or from 39,906 short tons in 1894, worth $435,060, to 39,240 short tons, valued at $370,895, in 1895.

Clays.—The value of the brick clays aggregated $9,000,000, practically the same as in 1894. The product of all other clays, i. e., potters' clays, amounted to $800,000, showing no essential change from 1894. The value of the clay products in the United States in 1895 was $65,319,806, as compared with $64,575,385 in 1894.

Fullers' earth.—This variety of clay was discovered in considerable quantity near Quincy, Fla., and began to compete with the imported material for filtering oils. Six thousand nine hundred tons were produced up to the close of 1895, worth $41,400 at the point of shipment. Other deposits have been located near River Junction, and near Ocala and Tampa, Fla. Extensions of the Quincy deposits have been found along the creeks to the north near Whigham, Ga., and deposits, the value of which has not yet been established, have been noted in North Carolina, Virginia, and South Dakota.

Cement.—Natural rock cement showed the same slight increase which it did in 1894, from 7,563,488 barrels (of 300 pounds each), worth $3,635,731, in 1894, to 7,741,077 barrels, worth $3,895,424, in 1895. Meanwhile the Portland cement industry progressed markedly, from a product of 798,757 barrels in 1894, worth $1,383,473, to 990,324 barrels in 1895, worth $1,586,830. The number of works decreased from 24 to 22.

ABRASIVES.

Millstones.—These increased from a value of $13,887 in 1894 to $22,542 in 1895.

Grindstones.—This industry shows a slight decline, from a value of $223,214 in 1894 to $205,768 in 1895.

Corundum and emery.—The year 1895 shows an increase from 1,495 long tons, in 1894, worth $95,936, to 2,102 tons, worth $106,256. The industry is still governed largely by the importation of low-priced emery from Asia Minor.

Oilstones.—There is little change in the trade, the old sources of supply increasing the product slightly—from a value of $136,873, in 1894, to $155,881, in 1895.

CHEMICAL MATERIALS.

Phosphate rock.—In 1895, for the first time, the product reached a million long tons (1,038,551), worth $3,606,094. The chief feature of interest is the fierce competition of the river-pebble deposits on Peace River in Florida. It is probable that the present low prices will gradually rise this year. Phosphate rock from western Tennessee has become a permanent factor in the Western trade.

Gypsum.—This product increased from 239,312 short tons in 1894 to 265,503 tons in 1895, with about a constant price.

Salt.—The principal feature of interest was the discovery of a very thick deposit of rock salt on Orange Island, Louisiana, near the old mines of Averys Island. The total product of salt in the United States increased from 12,967,417 barrels in 1894 to 13,669,649 barrels in 1895, but the total value decreased from $4,739,285 to $4,423,084.

Bromine.—The industry shows an increase. Including the bromine in bromide of sodium, made directly, in 1895 the total product was 517,421 pounds, worth $134,343. In 1894, 379,444 pounds were made, with a proportionate value.

Sulphur.—The point of principal interest is Sulphur Station, La., where the efficiency of the Frasch process has been increased by an air-lift pump by which 2,000 or 3,000 tons were brought to the surface, partly in 1896, but not yet sold. In addition, the Utah deposits sold about 1,000 tons.

Pyrite.—This industry shows a decline from 105,940 long tons in 1894 to 99,549 tons in 1895.

Borax.—The product declined from 14,680,130 pounds in 1894 to 11,918,000 in 1895, with a similar decline in value.

Fluorspar.—The product decreased in two years from 12,400 short tons in 1893 to 4,000 tons in 1895.

Chromic iron ore.—The product declined from 3,680 long tons in 1894 to 1,740 tons in 1895. The greater supply is imported from Smyrna, but there are prospects of some future imports from Canada.

PIGMENTS.

Barytes.—The product declined again, or from 23,335 long tons, worth $86,983, in 1894, to 21,529 long tons, worth $68,321, in 1895.

Metallic paints.—The product shows a substantial increase, both in amount and value, over 1894. The product in 1895 was 28,859 short tons, valued at $319,142, against 25,375 short tons, valued at $284,883, in 1894, a gain of 3,484 short tons, or about 14 per cent in amount, and of $34,259, or something over 12 per cent in value.

Ocher, umber, etc.—The product of ocher increased in nearly the same proportion as that of metallic paint—from 9,768 short tons in 1894, valued at $96,935, to 12,045 short tons, valued at $139,328, in 1895, a gain of 2,277 short tons, or about 23 per cent in amount, but of $42,393, or more than 43 per cent in value. The production of umber increased from 265 short tons, valued at $3,830, to 320 short tons, valued at $4,350. The sienna output increased from 160 tons to 275 tons, with a value more than doubled—from $3,250 to $6,950. The amount of soapstone ground for pigment increased to 270 short tons, valued at $3,200, from 75 tons, worth $525, in 1894. Pigment from slate increased from 2,650 tons to 4,331 tons.

Venetian reds.—A production of 4,595 short tons, valued at $102,900, is reported for 1895, against 2,983 short tons, worth $73,300, in 1894. With the exception of 1892, this was the largest product ever reported.

Cobalt oxide.—The product is limited to the amount extracted from the speiss obtained in lead smelting. It amounted to 14,458 pounds, worth $20,675.

Zinc white.—The production rallied from 19,987 short tons, worth $1,399,090, in 1894, to 20,710 tons, worth $1,449,700, in 1895.

MISCELLANEOUS.

Precious stones.—The rough gems of domestic production were valued at $113,621 in 1895, against $132,250 in 1894.

Mica.—The industry continues in the unsatisfactory condition mentioned in the preceding report, though the value of the product was slightly in excess of that of 1894. The mines yielded 44,325 pounds of cut mica, valued at $49,218, and 148 tons of scrap mica, worth $5,450. Added to this was about 40,000 pounds of small-sized sheet mica, worth $1,163, making a total value for the product in 1895 of $55,831. The value of all kinds of mica produced in 1894 was $52,388.

Feldspar.—The product increased 35 per cent, or from 17,200 long tons, worth $98,900, in 1894, to 23,200 long tons, worth $133,400, in 1895.

Flint.—The flint used in pottery, etc., in 1895 amounted to 36,800 long tons, worth $117,760.

Asphaltum.—The value of the product was about the same in 1895 as in 1894, being $348,281 and $353,400 respectively. This, taken in connection with an increase in output from 60,570 short tons to 68,163 short tons, indicates a sympathy with the general depression in values. The product was from California, Kentucky, Texas, and Utah.

Infusorial earth.—The product in 1894 was small, having a value of but $11,718, little more than half that of 1893. Better conditions prevailed in 1895, and the value of the product advanced to $20,514.

Asbestos.—Owing to the development of asbestos mines in Georgia, the product increased considerably, notwithstanding a large decrease in California's output. The product in 1895 was 795 short tons, worth $13,525, against 325 tons, valued at $4,463, in 1894. The Wyoming properties have not yet assumed commercial importance.

Magnesite.—This product still comes from California, and increased from 1,440 short tons, worth $10,240, in 1894, to 2,200 short tons, worth $17,000, in 1895.

Mineral waters.—The product was almost stationary, i. e., 21,569,608 gallons, sold at $3,741,846, in 1894, and 21,463,543 gallons in 1895, which sold at the higher value of $4,254,237.

Metallic products of the United States in 1895.

Product.	Quantity.	Value.
Pig iron .... long tons..	9, 446, 308	$105, 198, 550
Silver .... troy ounces..	55, 727, 000	a 72, 051, 000
Gold .... do....	2, 254, 760	a 46, 610, 000
Copper .... pounds..	392, 639, 964	38, 682, 347
Lead .... short tons..	161, 440	10, 655, 040
Zinc .... do....	89, 686	6, 278, 020
Quicksilver .... flasks..	36, 104	1, 337, 131
Aluminum .... pounds..	920, 000	464, 600
Antimony .... short tons..	450	68, 000
Nickel .... pounds..	10, 302	3, 091
Platinum .... troy ounces..	150	900
Total	....	281, 348, 679

a Coining value.

Nonmetallic products of the United States in 1895.

Product.	Quantity.	Value.
Bituminous coal .... short tons..	135, 118, 193	$115, 749, 771
Pennsylvania anthracite .... long tons..	51, 785, 122	82, 019, 272
Building stone	....	34, 688, 816
Petroleum .... barrels..	52, 983, 526	57, 691, 279
Natural gas	....	13, 006, 650
Brick clay	....	9, 000, 000
Clay (all other than brick) .... long tons..	360, 000	800, 000
Cement .... barrels..	8, 731, 401	5, 482, 254
Mineral waters .... gallons sold..	21, 463, 543	4, 254, 237
Phosphate rock .... long tons..	1, 038, 551	3, 606, 094
Salt .... barrels..	13, 669, 649	4, 423, 084
Limestone for iron flux .... long tons..	5, 247, 949	2, 623, 974
Zinc white .... short tons..	20, 710	1, 149, 700
Gypsum .... do....	265, 503	807, 447
Borax .... pounds..	11, 918, 000	595, 900
Mineral paints .... short tons..	50, 695	621, 552
Grindstones	....	205, 768
Fibrous talc .... short tons..	39, 240	370, 895
Asphaltum .... do..	68, 163	348, 281
Soapstone .... do..	21, 495	266, 495
Precious stones	....	113, 621
Pyrites .... long tons..	99, 549	322, 845
Corundum and emery .... short tons..	2, 102	106, 256
Oilstones, etc.	....	155, 881
Mica	....	55, 831

Nonmetallic products of the United States in 1895—Continued.

Product.	Quantity.	Value.
Barytes (crude) ....long tons..	21,529	68,321
Bromine ....pounds..	517,421	134,343
Fluorspar ....short tons..	4,000	24,000
Feldspar ....long tons..	23,200	133,400
Manganese ore ....do....	9,547	71,769
Flint ....do....	36,800	117,760
Monazite.........................pounds..	1,573,000	137,150
Graphite	....	52,582
Bauxite..........................long tons..	17,069	44,000
Sulphur........................short tons..	1,800	42,000
Fullers' earth ....do....	6,900	41,400
Marls ....do....	60,000	30,000
Infusorial earth ....do....	4,954	20,514
Millstones..	....	22,542
Chromic iron ore.................long tons..	1,740	16,795
Cobalt oxide ....pounds..	14,458	20,675
Magnesite ....short tons..	2,200	17,000
Asbestos ....do....	795	13,525
Rutile..............................pounds..	100	350
Total..	....	339,774,029

Résumé of the mineral products of the United States in 1895.

	Value.
Total value of metallic products	$281,348,679
Total value of nonmetallic products.......................	339,774,029
Estimated value of mineral products unspecified	1,000,000
Grand total..	622,122,708

TOPOGRAPHIC BRANCH.

The organization of the Topographic Branch remained practically unchanged from the close of the fiscal year 1894–95 to near the close of the fiscal year 1895–96, when Mr. Henry Gannett, until that time at its head, was transferred to other duties and the Director assumed immediate charge. As in the previous year, there were four sections, and they were continued, respectively, in charge of the same chiefs. To the Atlantic section, in charge of Mr. H. M. Wilson, was assigned all work to be done within the Appalachian Mountain region and the Atlantic Coastal Plain: to the Central section, in charge of Mr. John H. Renshawe, all work within the area of the Mississippi Valley, including Minnesota, the Dakotas, Nebraska, and eastern Wyoming; to the Rocky Mountain section, in charge of Mr. E. M. Douglas, all work in the Rocky Mountain States and Territories, including Texas; and to the Pacific section, in charge of Mr. R. U. Goode, all work in the Pacific States, including California, Washington, Oregon, and Idaho. The land and topographic surveys of the Indian Territory were continued in charge of Mr. C. H. Fitch.

DIVISION OF TRIANGULATION.

In the Atlantic section, Mr. S. S. Gannett established an astronomic station at Tuscaloosa, Ala. Observations for time and comparisons of chronometers for longitude were obtained on four nights, and 44 results were secured for latitude. From the point whose position was thus determined the primary control line was run across the Brookwood atlas sheet.

In the early part of the season an attempt was made by Mr. W. M. Beaman to obtain control by triangulation of the area of the phosphate deposits in western Tennessee, starting from triangulation points of the United States Coast and Geodetic Survey in the neighberhood of Nashville. This work was carried but a short distance, three stations having been established when it was found to be impracticable to continue, and the work was abandoned, with the intention of resuming it in the near future.

In the Rocky Mountain section, the triangulation of the plains in southern Colorado, commenced during the preceding season, was continued and extended during the past season by Prof. A. H. Thompson, who commenced work on May 20 and continued until the end of October, during which time the positions of 45 stations were determined. Thirty of these were primary stations, the remainder being classed as secondary. These fully controlled nine atlas sheets, besides parts of others, making a total area controlled of about 10,000 square miles.

In the Pacific section, triangulation and other control work was carried on during the summer by two parties in several distinct regions. In May, Mr. W. T. Griswold commenced triangulation in the Umpqua Valley, with the intention of carrying it across the Coast Ranges to the Pacific Coast, for the purpose of controlling the Coos Bay sheet. Before the completion of this work, however, forest fires began, rendering it impossible to continue. Mr. Griswold's party was, therefore, withdrawn from the neighborhood and ordered to the State of Washington for the purpose of running primary traverse lines for the control of the Tacoma and Seattle sheets. This was completed in October, whereupon, the smoke having cleared away, owing to early rains, Mr. Griswold returned to Oregon and succeeded in completing the triangulation needed in that area, supplementing it by primary traverse wherever triangulation was impracticable.

Early in July, Mr. S. S. Gannett proceeded to Ellensburg, Wash., for the purpose of initiating triangulation in the Cascade region of that State. He determined the position of Ellensburg by astronomic observations, obtaining therefor five comparisons of time with the accompanying observations, using San Francisco as a base, and 63 individual results for latitude. Having completed this determination, he measured a base line on a tangent of the Northern Pacific Railroad just northwest of Ellensburg. This line is about $4\frac{1}{6}$ miles in length, or, to be exact, 21,982.371 feet. It was measured twice, at night, with steel tape, and the usual corrections were made. From this base, triangulation was extended northward and westward into the Cascade Mountains. Seven stations were occupied and the positions of a number of well-known high peaks were determined and their altitudes measured. Work was discontinued about the middle of October, owing to severe weather.

In addition to the work mentioned above, triangulation was carried on in the Indian Territory for the control of the topographic work there. It was inaugurated by obtaining the position, by astronomic observation, of an initial point in the village of Savanna, on the Missouri, Kansas and Texas Railroad, in the Choctaw Nation. For the determination of longitude connection was had with St. Louis, and comparisons were made on five nights, with the necessary time observations. Latitude was determined from the mean of 35 results. A base line was measured on a tangent of the Missouri, Kansas and Texas Railroad, just north of Savanna, having a length of 4.7146 miles. The base was measured twice with a 300-foot steel tape, and the usual corrections were made. From this base line, triangulation was extended in all directions by two triangulation parties, the first in charge of Mr. S. S. Gannett, the second in charge of Mr. C. F. Urquhart. In the latter part of June, Mr. Gannett suffered a severe attack of typhoid fever, which necessitated his leaving the Territory, whereupon he was detailed to the State of Washington, as stated on a previous page. Triangulation was continued until late in the winter by Mr. Urquhart, and upon its discontinuance, in January, he was placed in charge of one of the subdivision parties in the Territory.

The results of the season's work in Indian Territory may be summarized in the statement that 49 primary stations have been selected, signals built upon them, and angles measured from them. By means of these stations an area of about 10,000 square miles, or about five-twelfths of the Territory, has been controlled.

DIVISION OF TOPOGRAPHY.

During the season there were in the field thirty-three topographic parties. Besides these, topographic work has been done by four parties in connection with the subdivision of lands in the Indian Territory, making altogether thirty-seven parties engaged in topographic work, which, with the three employed in triangulation, makes a total of forty.

The entire area surveyed by the topographic parties during the season was 48,066 square miles. Of this 42,386 square miles was newly mapped area, and 5,680 square miles consisted of revision of maps heretofore made whose scale and degree of detail are not regarded as adequate when measured by present standards.

Classifying the area done by the scales upon which it is designed for publication, it appears that 4,030 square miles are upon the scale of 1:62500, and 44,013 square miles were designed for the scale of 1:125000, the remainder, 23 square miles, being a special map on the scale of 1:15000.

The following table shows, by States, the areas surveyed during the past season, classified by scale of publication:

Topographic surveys by the United States Geological Survey in 1895–96.

State or Territory.	Scale of publication.		Total area.
	1 : 62500.	1 : 125000.	
Alabama		1,000	1,000
California	1,388		1,388
Colorado	475	2,142	2,617
Georgia		1,620	1,620
Idaho		860	860
Indian Territory		9,814	9,814
Kansas		1,000	1,000
Maryland		1,395	1,395
Michigan	400		400
Missouri		1,250	1,250
Montana			*a* 23
Nebraska		5,500	5,500
New Hampshire	437		437
New York	1,113		1,113
North Carolina		975	975
North Dakota		1,350	1,350
Oregon		890	890
South Dakota		3,150	3,150
Tennessee		1,810	1,810
Texas		3,418	3,418
Vermont	217		217
Virginia		1,882	1,882
Washington		1,182	1,182
West Virginia		1,775	1,775
Wyoming		3,000	3,000

a Special scale.

By the foregoing table and by the pocket map (Pl. I) it will be seen that work was prosecuted during the year in twenty-four States and Territories.

ATLANTIC SECTION.

This section has remained in charge of Mr. H. M. Wilson. Field work was prosecuted by seventeen parties during the season. The output of the section was 12,224 square miles, consisting of 1,767 square miles upon the scale of 1:62500 and 10,457 upon the scale of 1:125000. Twenty-three atlas sheets were completed and work was done upon seven others.

New Hampshire.—The work in New Hampshire comprised the survey of the two sheets known as Keene and Monadnock, near the southern border of the State. The work was placed in charge of Mr. R. D. Cummin, who commenced on May 14, with Mr. James McCormick as assistant. Work was prosecuted continuously from that time until the middle of September, when, having completed the two sheets mentioned, his party was transferred to New York for the remainder of the season.

Vermont.—The work in Vermont was at first placed in the hands of Mr. J. H. Jennings, with two assistants, who extended triangulation over the Castleton sheet, in the southwestern part of the State. In June Mr. Jennings was transferred to the Adirondack region, in New York, and the survey of the Castleton sheet was completed by Mr. E. B. Clark. This work was finished in August, and upon its completion Mr. Clark was also transferred to the work in New York.

New York.—The work in New York, as originally planned, comprehended the survey merely of the Bolton sheet, in the eastern part of the State. This was commenced by Mr. E. B. Clark on May 17, who was later joined by Mr. W. M. Beaman, who completed the sheet about September 1. Meantime, however, the State engineer of New York allotted the sum of $4,000, from an appropriation made by the legislature for the examination of sites for storage reservoirs in the Hudson River basin, for the payment of field expenses of topographic work in that region in cooperation with this Survey. For the prosecution of this work Mr. Jennings was detached from the work in Vermont, his place being supplied by Mr. Clark and by Mr. Sutton, with two assistants, from work upon the eastern shore of Maryland. These changes were made early in July. Later in the season other men were transferred to this field—Mr.

Beaman in September, upon the completion of the Bolton sheet, Messrs. Cummin and McCormick, upon the completion of the two sheets in New Hampshire, and Mr. Clark upon the completion of the Castleton sheet in Vermont. With this large force four sheets, viz, Schroon Lake, Paradox Lake, North Creek, and Glens Falls, were completed late in October or early in November, making five sheets altogether in New York State.

Maryland.—Work upon the eastern shore of Maryland was commenced on May 11, in charge of Mr. Frank Sutton, with J. W. Thom, James McCormick, J. H. Wheat, and three temporary employees as assistants. With this large force work was prosecuted rapidly in this region, and by July 1 six 15′ sheets had been completed, thus finishing three 30′ sheets, which bear the names Tolchester, Choptank, and St. Marys. Work was thereupon discontinued in this region, Mr. Sutton being detailed to the Hudson River basin in New York, Mr. Thom to Alabama, Mr. McCormick to New Hampshire, and Mr. Wheat to Tennessee.

Virginia.—Work in Virginia was prosecuted in two widely separated localities. The Amelia sheet, lying just west of Richmond and comprising the Richmond Triassic coal field, was surveyed by Mr. A. M. Walker. He commenced work on May 21 and completed the survey late in December.

The other locality is in southwest Virginia, and consisted of the revision of the unrevised part of the Bristol sheet, thus completing it, and the commencement of the revision of the Abingdon sheet. This work was done by Mr. Gilbert Thompson, who commenced the work early in June and completed it early in November.

West Virginia.—The work in this region consisted of revision of sheets lying along the upper waters of the Kanawha River, which was executed by Mr. Hersey Munroe. The first work undertaken was the completion of the revision of the Raleigh sheet, which was commenced the year before. Upon its completion he began the revision of the Oceana sheet, but the necessities of the geological work required that the completion of this sheet be postponed, and he devoted the remainder of the season to the revision of the Kanawha Falls sheet. This was undertaken and pushed forward rapidly, and was completed in November.

Tennessee.—The work in Tennessee was prosecuted in three different regions. The revision of the Maynardville sheet, which was commenced several years ago, was carried forward to completion by Mr. J. H. Wheat, who was ordered there from Maryland early in July. Upon its completion, in September, he took charge of work upon the Cowee sheet in North Carolina.

The Standing Stone sheet, which was commenced by Mr. A. E. Murlin the preceding season, was completed by him. He began work on May 10 and finished the sheet in July. Thereupon he was sent to the phosphate region, in the neighborhood of Columbia, in the western part of the State, in the survey of which he was occupied during the remainder of the season, until late in November. The area surveyed in this region was not limited by atlas-sheet lines, and embraced localities economically important by reason of their phosphate deposits. The area surveyed includes parts of three sheets, to be known as Columbia, Linden, and Waynesboro.

North Carolina.--The work in North Carolina was in the extreme western part of the State, and consisted in the revision of the Cowee sheet. This was commenced by Mr. Charles E. Cooke, with one assistant, on May 16. Early in July Mr. Cooke was detached from this work and sent to Indian Territory to take charge of a subdivision party there, and the work was for a time left in the hands of his assistant, Mr. Glenn S. Smith. Upon the completion of the revision of the Maynardville sheet, in the latter part of August, Mr. J. H. Wheat took charge of the party and carried forward the work to completion in November.

Georgia.—The work in this State consisted entirely of revision. In the northern part of the State large portions of the Dalton and Ellijay sheets were revised, Messrs. Merrill Hackett and W. L. Miller being at first assigned to this work. Early in July, however, it appeared advisable to make a change in the arrangement of the parties in this region, and Mr. Hackett was transferred to Rome, Ga., to revise sheets in that neighborhood, Mr. Miller being left temporarily in charge of the Dalton work. About August 15 Mr. R. H. McKee was transferred from Alabama and given charge of that work, Mr. Miller remaining as his assistant. The revision of these sheets, with small portions of adjoining sheets in Tennessee, was completed early in November.

In July Mr. Merrill Hackett commenced revision of the Tallapoosa (Ala.) and Rome (Ga.) sheets. He completed the former and about one-third of the latter by November, when work was discontinued.

Alabama.—Besides the revision of the Tallapoosa sheet, a new sheet, the Brookwood, including a part of the Black Warrior coal field, was surveyed. The work was at first placed in the hands of Mr. R. H. McKee, who was subsequently transferred to Georgia, his place being taken by Mr. J. W. Thom, who carried the work to completion, finishing it in November.

CENTRAL SECTION.

This section has remained throughout the year in charge of Mr. J. H. Renshawe. Six parties have been in the field engaged in topographic work. The total area surveyed by the section is 15,650 square miles, of which 14,650 square miles consist of new work. Classified by scale, 400 square miles are upon the scale of 1:62500 and 15,250 square miles upon the scale of 1:125000. The work of this section completes 26 atlas sheets.

Michigan.—In 1893 a considerable area was surveyed by private parties, with the utmost care and thoroughness, in the upper peninsula of Michigan, in the neighborhood of Crystal Falls and Iron River. It is of irregular outline, with limits which do not conform to the plan of the atlas sheets of the Geological Survey. Copies of this work having been furnished to the Survey, it seemed desirable to extend the work upon the borders in such wise as to complete atlas sheets. For this purpose Mr. H. L. Muldrow was detailed, with an assistant. Commencing work on June 1, he continued until the end of October, covering an area estimated at 400 square miles. This completed three quarter-degree sheets, which bear the names Iron River, Crystal Falls, and Sagola.

Missouri.—In the zinc and iron regions in the southeastern part of Missouri the State geological survey had completed three 15′ sheets. It being desirable to extend the work in that region, Messrs. W. H. Lovell and Paul Holman were detailed for the purpose of completing two 30′ sheets embracing the area surveyed by the State, viz, the Bonne Terre and the Ste. Genevieve. This work was commenced in the latter part of May and completed toward the end of December.

North Dakota, South Dakota, and Minnesota.—In these States a large number of 15′ sheets have been completed, but under a recent decision to reduce the scale of this region to 1:125000, thus increasing the area covered by the sheets to 30′ in either direction, many of these larger sheets were only partially surveyed. To complete them Mr. H. S. Wallace was detailed, with two assistants, Messrs. W. H. Griffin and Basil Duke. He commenced work on June 1, and by the middle of September had completed the unfinished portions of nine sheets, an area of about 4,000 square miles. Upon its completion, Mr. Wallace and his party were ordered to Kansas, where they devoted the remainder of the season to the revision of the Cottonwood Falls sheet, in the central part of the State. They closed work in November.

Nebraska.—The condition of the work above described for the Dakotas prevailed in central Nebraska, where numerous 30′ sheets lay unfinished. For their completion Mr. R. C. McKinney was detailed, with two assistants, Messrs. Nat. Tyler, jr., and C. W. Goodlove. He commenced work on July 1, and continued from that time until early in November, completing five sheets, known as Loup, St. Paul, David City, Wahoo, and Lincoln.

Mr. H. B. Blair, with two assistants, Messrs. A. B. Searle and L. F. Garrard, jr., was detailed for the survey of three 30′ sheets in the western part of Nebraska, including the valley of the North Platte River. His party commenced work on June 1 and ended about November 1, having nearly completed these sheets.

Wyoming.—Mr. W. S. Post, with two assistants, Messrs. Duncan Hannegan and J. L. Johnson, was detailed for the survey of an area in eastern Wyoming adjoining that of Mr. Blair in Nebraska and comprising a part of the valley of the North Platte River. This work was commenced about June 1 and closed early in November, three 30′ sheets having been surveyed.

ROCKY MOUNTAIN SECTION.

This section has remained through the year in charge of Mr. E. M. Douglas, who has had six parties in the field. The party has surveyed an area of 6,058 square miles upon the scale of 1:62500, and 5,560 square miles upon the scale of 1:125000. About 2,700 square miles of this area consisted of revision of earlier maps, the remainder being new work. Besides the work upon these two scales, a special map, covering 23 square miles, has been prepared of the region about Butte, Mont., upon a scale of 1:15000.

Montana.—For the preparation of a detailed map of the region immediately surrounding Butte, Mont., Mr. R. H. Chapman, with one assistant, was detailed. He commenced the work on May 20 and completed it early in September, having mapped an area of 23 square miles. The work was done with plane table and stadia, controlled by triangulation and Y levels. Upon the completion of this work Mr. Chapman undertook the extension of triangulation over a 30′ atlas sheet lying immediately east of Butte, but the severity of the weather rendered it inadvisable to continue this work. He was then ordered to Aspen, Colo., to extend slightly the detailed map of that region, after which he was sent to Texas to assist in completing the area under survey there.

Colorado.—Work was prosecuted in Colorado in two areas. The revision of the plains sheets was continued, Messrs. W. H. Herron and W. J. Lloyd being detailed for this work. They commenced work in May and continued it until December, completing two sheets, the Elmoro and Spanish Peaks.

Early in May Mr. Frank Tweedy was sent to Cripple Creek, Colo., for the purpose of discovering the township and section corners and locating them upon the map of that region. Upon the completion of this work he proceeded to the San Juan country, where he devoted the remainder of the season to the survey of the Silverton and La Plata sheets. These were finished early in November.

Texas.—Work in Texas was prosecuted in two areas, the central and western parts of the State. Mr. T. M. Bannon, with one assistant, was detailed for work in the central part of the State, his work consisting in the completion of the revision of the Austin sheet. This was undertaken early in May and completed in September, whereupon he proceeded with his party to the area of the Brackett sheet and surveyed the unfinished half thereof, completing it in January.

The work in western Texas was intrusted to Mr. C. C. Bassett, with one assistant. It consisted in the survey of six sheets, most of them fractional, bordering upon the Rio Grande. Mr. Bassett commenced work in the latter part of May and continued it until early in December, aided during the last month by Mr. R. H. Chapman. Mr. Bassett's health being precarious, he was ordered to Washington before completing the area assigned him, and as the Butte sheet was needed by the geologists, Mr. Chapman also was ordered in for the purpose of drawing that map. As it seemed desirable to finish the area already assigned in this region, and as the winter is the best time of the year for working there, Mr. W. J. Lloyd volunteered to take charge of the party and complete the survey. He commenced work in January and finished it in March, completing two sheets by the survey of an area of a little over 400 square miles.

PACIFIC SECTION.

This section has been throughout the year in charge of Mr R. U. Goode. An area of 4,320 square miles has been surveyed, of which 1,388 are upon the scale of 1:62500 and 2,932 upon the scale of 1:125000. Twelve atlas sheets have been completed, besides portions of other sheets. Seven parties have been maintained in the field during the season, as shown in detail below.

Idaho.—The work in Idaho consisted in the completion of the Hailey sheet and the survey of about half of the Red Fish Lake sheet, both upon the scale of 1:125000. Mr. Perkins, to whom this work was assigned, took the field with one assistant on June 1 and concluded field work in the latter part of October, being driven out by bad weather.

Washington.—To Mr. George E. Hyde, with two assistants, was assigned the task of surveying practically the whole of the Tacoma 30′ sheet and the north half of the Seattle 30′ sheet. He commenced work on May 20 and continued, in spite of bad weat[illegible] until Dece[illegible] 1, succeeding in finishing the area [illegible]

[illegible] Barnard, with two assistants, was [illegible] leting the Roseburg sheet, in the [illegible] ch of the Coos Bay sheet, lying [illegible] e westward, as the season would [illegible] led in completing the Roseburg [illegible] perienced from forest fires, but [illegible] Coos Bay sheet these fires set in [illegible] smoke to such an extent as to [illegible] sing. In spite of this difficulty, [illegible], Mr. Barnard completed by the middle of November about half of the Coos Bay sheet.

California.—Two parties were at work in California. Mr. R. B. Marshall, with two assistants, which number was increased to three toward the end of the season, undertook the survey of three 15′ sheets lying south of San Francisco Bay, viz, Palo Alto, San Jose, and Mount Hamilton, which include a section across the Santa Clara Valley, with a portion of the mountains on either side. Commencing the work in June, Mr. Marshall was occupied on it until the middle of December, completing the area. A little work also was done by him upon the Mount Tamalpais sheet, just northwest of the Golden Gate, in order to complete the area.

A second party, under Mr. L. C. Fletcher, surveyed an area embracing San Luis Obispo and surrounding country. With one assistant he commenced work early in June, and completed, by the end of November, an area comprised upon four sheets, but, since three of them were but partial sheets, equivalent in area to about three. These sheets bear the names San Luis Obispo, Arroyo Grande, Cayucas, and Port Harford survey of the Silverton and La Plata sheets. These were finished early in November.

Texas.—Work in Texas was prosecuted in two areas, the central and western parts of the State. Mr. T. M. Bannon, with one assistant, was detailed for work in the central part of the State, his work consisting in the completion of the revision of the Austin sheet. This was undertaken early in May and completed in September, whereupon he proceeded with his party to the area of the Brackett sheet and surveyed the unfinished half thereof, completing it in January.

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Washington.—To Mr. George E. Hyde, with two assistants, was assigned the task of surveying practically the whole of the Tacoma 30′ sheet and the north half of the Seattle 30′ sheet. He commenced work on May 20 and continued, in spite of bad weather, until December 1, succeeding in finishing the area assigned him.

Oregon.—To Mr. E. C. Barnard, with two assistants, was assigned the work of completing the Roseburg sheet, in the Umpqua Valley, with as much of the Coos Bay sheet, lying upon the Pacific Coast to the westward, as the season would permit. Mr. Barnard succeeded in completing the Roseburg sheet before trouble was experienced from forest fires, but shortly after commencing the Coos Bay sheet these fires set in and covered the country with smoke to such an extent as to prevent any work except traversing. In spite of this difficulty, however, Mr. Barnard completed by the middle of November about half of the Coos Bay sheet.

California.—Two parties were at work in California. Mr. R. B. Marshall, with two assistants, which number was increased to three toward the end of the season, undertook the survey of three 15′ sheets lying south of San Francisco Bay, viz, Palo Alto, San Jose, and Mount Hamilton, which include a section across the Santa Clara Valley, with a portion of the mountains on either side. Commencing the work in June, Mr. Marshall was occupied on it until the middle of December, completing the area. A little work also was done by him upon the Mount Tamalpais sheet, just northwest of the Golden Gate, in order to complete the area.

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During the winter and spring months these parties, with the exception of Mr. Lloyd's party in western Texas, have been in the office in Washington, engaged in the reduction of triangulation and observations for astronomically determined positions, in reducing and transferring their plane-table sheets, and in the preparation of finished maps. All the field work of the past season has been thus put in final shape.

INDIAN TERRITORY SECTION.

Under the provisions of an act of Congress approved March 2, 1895, an appropriation of $200,000 was made for the survey and subdivision of the lands of Indian Territory, and the work was placed, in the discretion of the Secretary of the Interior, in charge of the Director of the Geological Survey. A plan of operations was drawn up, which was approved by the Secretary of the Interior on March 21, and preparations were immediately made to begin the work, Mr. C. H. Fitch being placed in immediate charge. The requisite animals and camp equipage were purchased and shipped to South McAlester, in the Choctaw Nation, the headquarters selected for the work. Toward the close of March two parties were placed in the field, and on April 1 work was commenced. One of these parties, under Mr. G. T. Hawkins, took up the Indian base at its point of intersection with the east boundary of the Chickasaw Nation and ran it eastward 50 miles. The other party, under Mr. W. J. Peters, ran the second guide meridian southward as a principal meridian. Thereafter these parties continued the work of running standard lines. Early in April two parties, under Mr. H. L. Baldwin, jr., and Mr. R. O. Gordon, were placed in the field for the purpose of running township exteriors, and shortly thereafter eight parties for running the subdivision lines of the townships were added. These subdivision parties were grouped two in a camp, and each such group was placed in charge of a topographer of the Survey, whose duties were to superintend the work of subdivision by the surveyors and to map the country subdivided. The men placed in charge of these parties at first were Messrs. Van H. Manning, D. C. Harrison, R. A. Farmer, and R. M. Towson.

From time to time this force has been increased, two parties for running exteriors having been added, besides eight surveyors for the subdivision parties, so that by October 1 there were in the field and at work two parties for running standard lines, four parties for running exteriors, and sixteen surveyors engaged in subdividing the townships, the latter class being grouped in four parties, in charge of topographers permanently employed by this office. The changes in the personnel of this section have been so numerous and frequent that it seems scarcely worth while to recapitulate them.

The work was continued through the winter and spring, and was stopped only for a brief period beginning June 1, because of the expenditure of the appropriation and delay in the passage of the bill carrying a new appropriation for continuation of the work. It was apprehended that, owing to the shortness of the days and bad weather, winter work would not be economic, but it was found by experience that, probably owing to less illness among the men and the fact that the leaves were off the trees, winter work was much more rapid and economical than work in the warm season.

The progress in subdivision work may be summarized in the statement that 21,314 miles of line have been run. Of this mileage, 1,339 miles are of standard lines, 3,087 are township exteriors, and 16,888 are subdivision or sectional lines and meander lines. The work thus far done completes the subdivision of 249 complete townships and 36 fractional townships, embracing the Seminole Nation, nearly all of the Creek Nation, and the western parts of the Choctaw and Cherokee nations.

The mapping of topography has followed closely the work of subdivision. Up to this date an area closely estimated at 9,814 square miles has been mapped.

Since the entire mileage required for the subdivision of the Territory is estimated at 47,000 miles, it will be seen by the above figures that about 45 per cent of the area of the Territory has been completed.

There has been expended upon the Indian Territory survey up to the present date the sum of $196,500. Of this, about

$20,000 has been expended upon office work, and $25,000 upon outfitting, leaving as the current expense of field work $151,500, and the total expense of field work, including outfitting, $176,500. Under the rates allowed by law to contractors for doing this work, the completed mileage, as above stated, would have earned to contractors the sum of $198,400 for field work and the examination of surveys. It appears, therefore, that the Geological Survey has not only executed the work of subdivision, but has in addition carried on primary triangulation and prepared maps of the area subdivided, at a total saving to the Government of $21,900, to which should be added the value of the outfit, which will be practically sufficient for the completion of the subdivision work.

The office work of this section consists in the rewriting of subdivision notes from the rough notes made by the surveyors in the field, the preparation of copies of the same, and the drawing of plats and maps. The preparation of the first draft of the subdivision notes from the surveyors' rough notes is done at South McAlester, the headquarters of the Survey in Indian Territory. The remainder of the office work is done in Washington.

Of the state of progress of office work in Indian Territory it is not practicable to make a definite report, owing to the fact that a large amount of work has been commenced and is in various stages of advancement. In the writing of these notes many questions which can be answered only by the surveyors continually arise, involving the laying aside of the work until correspondence can be had with the surveyors and the questions settled. It is only in regard to the notes and plats received in Washington that definite statements can be made. At the present date the notes of 6,407 miles of survey have been received. These comprise, besides the notes of standard lines and township exteriors, the subdivision notes of 78 townships. Practically all of these have been copied, three copies being made, for filing with the Land and Indian offices.

The plats of 42 townships have been drawn and a number of others are in various stages of progress.

The main reason for the slow progress in office work has been that it was considered desirable to develop and push the field work considerably in advance of the office work, and not to organize the office force on an extensive scale until toward the close of the fiscal year. This is now being done, and henceforth the work will progress rapidly and soon overtake the field survey. It has been found that the office work depends entirely upon the progress made in the preparation of the first draft of the notes from the surveyors' rough notes, and that it is difficult to obtain men sufficiently acquainted with the details of Land Office requirements and methods of complying with them. This difficulty, however, has been largely removed. The second reason for slow progress is the constant delays caused by the necessity of corresponding with the surveyors for the purpose of making corrections and supplying omissions in the rough field notes. It is anticipated, however, that with the training the men have now received this will cause comparatively little delay in future.

PUBLICATION BRANCH.

DIVISION OF ILLUSTRATIONS.

The Division of Illustrations remained in charge of Mr. De Lancey W. Gill, who was assisted throughout the year by Mr. John L. Ridgway, Mr. H. Hobart Nichols, Mr. Daniel W. Cronin, Mr. F. W. von Dachenhausen, and Mr. H. Chadwick Hunter, and for the greater part of the year by Mr. Wells M. Sawyer. Mr. William A. Wansleben, Mr. W. F. Hopson, and Miss Frances Wieser were employed in the work from time to time for short periods.

Mr. Ridgway has assisted Mr. Gill in the general supervision of the work of the division, and has also made a large number of paleontologic drawings. Mr. Nichols's work, as in previous years, has been the preparation of geologic and topographic landscapes and the retouching of photographs. Mr. Cronin and Mr. Von Dachenhausen have been engaged in the preparation of topographic and geologic maps and sections. Mr. Hunter and Mr. Sawyer have been employed in the preparation of paleontologic drawings. Mr. Wansleben was employed during the months of April, May, and June in the preparation of special maps for the report on the coal and gold deposits in Alaska. Miss Wieser has been employed from time to time during the year in the preparation of miscellaneous paleontologic drawings. Mr. W. F. Hopson has been similarly employed, and has been working under the supervision of Professor Marsh, at New Haven, Conn.

Drawings to the number of 2,077 were produced during the year, classified as follows: Geologic landscapes, 50; geologic sections and diagrams, 673; geologic and topographic maps, 106; paleontologic drawings, 930; miscellaneous drawings, 318.

Engraved proofs of 518 illustrations were received during the year from the Public Printer and examined for criticism and revision. Original drawings representing the illustrations for one annual report, two monographs, and nine bulletins were transmitted to the Public Printer during the year. These illustrations were marked for reproduction as follows: Chromolithography, 127; photolithography, 17; half-tone engraving, 187; photoengraving, 418.

PHOTOGRAPHIC LABORATORY.

The photographic laboratory has been, as in previous years, in charge of Mr. J. K. Hillers, assisted by Messrs. C. C. Jones, John Erbach, and Charles A. Ross, photographic printers. The following statement shows the number of negatives and prints made during the year:

Photographic negatives and prints made during 1895-96.

Size.	Negatives.	Prints.
28 by 34	114	621
22 by 28	91	419
20 by 24	381	2,255
14 by 17	126	522
11 by 14	281	5,125
8 by 10	351	2,176
6 by 8	271	2,238
5 by 8	290	1,362
4 by 5	937	709
Total	2,842	15,427

EDITORIAL DIVISION.

TEXTUAL PUBLICATIONS.

Mr. Philip C. Warman remained in charge of this section, and was assisted throughout the year by Mr. George M. Wood, and for a portion of the time by Miss A. B. Dawson. He also had the assistance for two months of Mr. James H. Blodgett.

The work progressed in a highly satisfactory manner, and at the close of the fiscal year no paper that had been received remained unedited and no proof remained unread. The work of this section is not of current nature, but fluctuates in amount from time to time. It is usually at its maximum during the summer months. Following are lists of the manuscripts prepared for the printer and the proofs read and corrected during the year:

Manuscript edited during the year 1895–96.

	Pages
Sixteeenth Annual Report (in part)	1,350
Seventeenth Annual Report (in part)	3,552
Monograph XXVII	891
Monograph XXVIII	735
Monograph XXIX (in part)	1,036
Monograph ——— (by G. H. Stone, in part)	566
Monograph ——— (by Shaler, Woodworth, and Foerste)	660
Bulletin No. 132	45
Bulletin No. 133	150
Bulletin No. 134	68
Bulletin No. 135	250
Bulletin No. 138	426
Bulletin No. 139	329
Bulletin No. 140	822
Bulletin No. 141	209
Bulletin No. 142	90
Bulletin No. 143	257
Bulletin No. 145	303
Bulletin No. 146	312
Text for geologic folios Nos. 13, 18, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30	824
Total number of manuscript pages edited	12,875

Proof read during the year 1895–96.

	Pages.
Sixteenth Annual Report (in part)	2,170
Seventeenth Annual Report (in part)	300
Monograph XXVI	260
Bulletins 126, 127 (in part), 130, 131, 132, 133, 134, 135, 136, 140	1,843
Text for geologic folios Nos. 13, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29 (all folio pages)	54
Total number of printed pages read	4,627

GEOLOGIC MAPS.

This section was continued under the charge of Mr. Bailey Willis, who was assisted by Mr. George W. Stose and Mr. Olaf A. Ljungstedt. During Mr. Willis's absence in the field the work of the section was in the charge of Mr. Stose.

The textual descriptions of the folios were edited by Mr. Willis and Mr. Warman jointly. Mr. Stose gave his attention principally to proof reading, while Mr. Ljungstedt was employed chiefly in the preparation of manuscript drawings.

During the year twelve geologic folios have been published, Nos. 15 to 26, inclusive. These are listed below, preceded by Nos. 1 to 14, previously published, making the list complete to date.

Geologic folios published during the year 1895–96, and previously.

No.	Name of sheet.	State.	Limiting meridians.	Limiting parallels.	Area, in square miles.	Price, in cents.
1	Livingston	Montana	110°–111°	45°–46°	3,354	25
2	Ringgold	Georgia Tennessee	85°–85° 30′	34° 30′–35°	980	25
3	Placerville	California	120° 30′–121°	38° 30′–39°	932	25
4	Kingston	Tennessee	84° 30′–85°	35° 30′–36°	969	25
5	Sacramento	California	121°–121° 30′	38° 30′–39°	932	25
6	Chattanooga	Tennessee	85°–85° 30′	35°–35° 30′	975	25
7	Pikes Peak	Colorado	105°–105° 30′	38° 30′–39°	932	25
8	Sewanee	Tennessee	85° 30′–86°	35°–35° 30′	975	25
9	Anthracite-Crested Butte.	Colorado	106° 45′–107° 15′	38° 45′–39°	465	50
10	Harpers Ferry	Virginia West Virginia Maryland	77° 30′–78°	39°–39° 30′	925	25
11	Jackson	California	120° 30′–121°	38°–38° 30′	938	25

Geologic folios published during the year 1895–96, and previously—Continued.

No.	Name of sheet.	State.	Limiting meridians.	Limiting parallels.	Area, in square miles.	Price, in cents.
12	Estillville	Virginia, Kentucky, Tennessee	82° 30′–83°	36° 30′–37°	957	25
13	Fredericksburg	Maryland, Virginia	77°–77° 30′	38°–38° 30′	938	25
14	Staunton	Virginia, West Virginia	79°–79° 30′	38°–38° 30′	938	25
15	Lassen Peak	California	121°–122°	40°–41°	3, 634	25
16	Knoxville	Tennessee, North Carolina	83° 30′–84°	35° 30′–36°	925	25
17	Marysville	California	121° 30′–122°	39°–39° 30′	925	25
18	Smartsville	California	121°–121° 30′	39°–39° 30′	925	25
19	Stevenson	Alabama, Georgia, Tennessee	85° 30′–86°	34° 30′–35°	980	25
20	Cleveland	Tennessee	84° 30′–85°	35°–35° 30′	975	25
21	Pikeville	Tennessee	85°–85° 30′	35° 30′–36°	969	25
22	McMinnville	Tennessee	85° 30′–86°	35° 30′–36°	969	25
23	Nomini	Maryland, Virginia	76° 30′–77°	38°–38° 30′	938	25
24	Three Forks	Montana	111°–112°	45°–46°	3, 354	50
25	Loudon	Tennessee	84°–84° 30′	35° 30′–36°	969	25
26	Pocahontas	Virginia, West Virginia	81°–81° 30′	37°–37° 30′	951	25

The following folios advanced to the stage of color-printing and will issue from the press before the close of 1896:

Geologic folios in press.

No.	Name of sheet.	State.	Limiting meridians.	Limiting parallels.	Area, in square miles.	Price, in cents.
27	Morristown	Tennessee	83°–83° 30′	36°–36° 30′	963	25
28	Piedmont	Virginia, Maryland, West Va.	79°–79° 30′	39°–39° 30′	925	25
29	Nevada City:					
	Nevada City	California	121° 00′ 25″–121° 03′ 45″	39° 13′ 50″–39° 17′ 16″	11.65	50
	Grass Valley	California	121° 01′ 35″–121° 05′ 04″	39° 10′ 22″–39° 13′ 50″	12.09	50
	Banner Hill	California	120° 57′ 05″–121° 00′ 25″	39° 13′ 50″–39° 17′ 16″	11.65	50
30	Yellowstone National Park:					
	Gallatin, Canyon, Shoshone, Lake	Wyoming	110°–111°	44°–45°	3, 412	75

Of these, the Nevada City folio contains three maps of distinct areas, and the Yellowstone Park folio four such maps.

The labor involved in preparing each of these was much more than that involved in the preparation of any single or ordinary folio.

In addition to the foregoing, there were in hand on June 30, in various stages of engraving, the following folios:

Geologic folios in an advanced stage of preparation.

No.	Name of sheet.	State.	Limiting meridians.	Limiting parallels.	Area in square miles.	Price, in cents.
.....	Briceville	Tennessee	84°–84° 30′	36°–36° 30′	963	....
.....	Buckhannon	West Virginia	80°–80° 30′	38° 30′–39°	932	....
.....	Franklin	Virginia West Virginia	79°–79° 30′	38° 30′–39°	932	....
.....	Gadsden	Alabama	86°–86° 30′	34°–34° 30′	986	....
.....	Pyramid Peak	California	120°–120° 30′	38° 30′–39°	932	....
.....	Tazewell	Virginia West Virginia	81° 30′–82°	37°–37° 30′	950	....

During the autumn proof reading was continued on the geologic map of the State of New York, which had been in preparation for a number of years, under the general direction of Mr. W. J. McGee, for Prof. James Hall, State geologist of New York. In January an edition of 1,000 copies of this map was issued, and the cooperation between the National Survey and the State Survey in the matter of the preparation of the map in question ceased.

Mr. Willis's duties as editor of geologic maps have included the examination of all original maps and sections submitted for publication in the geologic folios, the reading of descriptive texts for these folios, and attention to such administrative details of the work of the Survey as bear upon the preparation of material for the atlas. During the winter he carried on correspondence with the geologists most interested in the mapping of the Pleistocene formations, and with their aid devised a color scheme that has met with provisional approval. The standard patterns and colors adopted for this scheme have been printed and are available for use as samples in the preparation of Pleistocene maps.

TOPOGRAPHIC MAPS.

The importance of having within the Survey an editor of topographic maps has been fully established by the results obtained during the past two years. Under the present division of duties, the editor, Mr. Marcus Baker, is in charge of the original manuscript topographic atlas sheets, these being turned over to him from time to time as completed. The sheets are carefully examined and prepared for engraving, the examination consisting in comparing the maps with other maps and published material relating to the regions, when there is such published material to make comparison with. The preparation consists mainly in the correction of such errors or defects as are discovered in the course of this examination and in securing proper uniformity. After the sheets have successfully undergone examination and criticism, they are approved for engraving and sent to the Division of Engraving and Printing, through the office of the Director. After engraving, proofs are submitted and carefully read, before the sheets are approved for printing.

At the beginning of the fiscal year, viz, on July 1, 1895, there were in hand for engraving 96 atlas sheets. Of this number, 26 had been sent to the engraver and work upon them was in various stages of progress. The examination and engraving of the remaining 70 had not been begun. These sheets comprise surveys made in the field seasons of 1892, 1893, and 1894. During the year the engraving and printing of 43 maps were completed, and more or less progress was made on 34 others. All the work of 1893 and 1894 was at the close of the year either completed or far advanced, and of the 51 sheets submitted as the outcome of the field season of 1894, 10 are engraved and printed and more or less progress has been made upon 15 others.

As the outcome of the field season of 1895, 57 sheets have been submitted for engraving. Summarizing the work of the year, we have: Number of new topographic sheets whose engraving and printing were completed, 42; in hand June 30, 1896, 26; new sheets in hand for engraving on which work is not yet begun, 82.

The arrearages in engraving work of 1892 and 1893 were nearly brought up to date. Of old sheets out of print, or which were needed to serve as bases for folios or for other purposes, 59 were revised.

Throughout the year, as in previous years, Mr. Baker served as secretary of the United States Board on Geographic Names, the work of which is so closely related to that of the Geological Survey and so useful to it. He also prepared a map for the Venezuelan Boundary Commission, and on May 11, at the request of the chairman of that body, he was detailed to the Commission, and since that date has given most of his time to its work, continuing, however, to exercise a general supervision over the map editing of the Survey.

Mr. Baker was assisted during the year by Mr. H. W. Elmore, and for longer or shorter periods by Miss A. B. Dawson and Mr. R. M. Towson, the last-named having been employed in the work fifteen days only. Mr. James McCormick assisted in the editorial work in March and April, by temporary detail, and in May was permanently assigned to the section.

DIVISION OF ENGRAVING AND PRINTING.

Mr. S. J. Kübel was continued in charge of this division as chief engraver, assisted by Mr. Henry C. Evans, foreman of copper-plate engravers; Mr. Robert H. Payne, in charge of the transferring to stone; Mr. Joseph Eckert, in charge of the work of the lithographic power presses; and Mr. Oscar Schleichert, in charge of stone work.

Under authority granted in the urgent deficiency bill, additional space was rented for the use of this division in May, 1896, and preparations were at once made to increase the plant and force. Four lithographic steam presses and one type press are in operation, and two more lithographic steam presses are now being installed. The employees now upon the rolls number 55, classified as follows: Copper-plate engravers, 17; lithographic engravers, 6; printers, 32. Additions are now being made to the force of copper-plate engravers through the medium of the Civil Service Commission.

The energies of the division were directed throughout the year principally to the engraving and printing of geologic folios and topographic atlas sheets, though considerable attention was given to collateral and incidental tasks.

Engraving of topographic sheets.—New sheets to the number of 48 were engraved complete, distributed by States as follows: California, 4; Colorado, 2; Georgia, 1; Kansas, 6; Louisiana, 1; Maryland, 1; Michigan, 2; Minnesota, 2; Massachusetts, 1; Nebraska, 4; North Dakota, 4; North Carolina, 2; New York, 1; Oregon, 1; Pennsylvania, 4; South Dakota, 3; Texas, 4; Wisconsin, 1; Wyoming, 4. Of this number 42 were printed. Of those engraved, 18 are reproductions and combinations, on the scale of 2 miles to the inch, of 72 sheets the originals of which were drawn on the scale of 1 mile to the inch. The amount of engraving represented by each such resultant two-mile sheet, reduced as it is from four one-mile-scale sheets, is fully three times as great as that involved in the preparation of a sheet on the one-mile scale. The introduction of much detail formerly omitted in the engraving of one-mile sheets has somewhat lessened the expected output of the year. The standard of execution, however, has been maintained, and, where possible, has been raised. In addition to the sheets completed, 34 had been received and the engraving of 19 of them was in hand at the close of the year.

Engraving of geologic folios.—Lists of the geologic folios published during the year and those in press and in preparation have been given on pages 112, 113, and 114.

The editions of the geologic folios completed and delivered during the year reached a total of 65,857 copies, averaging about 5,000 copies each. This total is 31,158 in excess of the total number printed during the previous fiscal year.

Of the standard topographic atlas sheets there were printed 79,735 copies; of the east and west Washington double or special sheet, 3,500 copies; of the Lake Tahoe special map (4 sheets), 500 copies; of the special map of Philadelphia and vicinity, 3,364 copies; of the special map of Mount Washington and vicinity, 960 copies; of the United States nine-sheet map, 260 copies of sheet No. 6 and 72 of the accompanying index sheet; of the six-sheet geologic map of the State of New York (complete), 1,120 copies, and of the base of the same map, 416 copies. Besides, there were printed Land Office plats for use in Indian Territory surveys to the number of 1,410 copies, and many cards, diagrams, etc.

ADMINISTRATIVE BRANCH.

DIVISION OF DOCUMENTS, CORRESPONDENCE, AND RECORDS.

This division was continued in general charge of the chief clerk, Col. H. C. Rizer, the custody and distribution of documents and stationery being under the immediate charge of Dr. W. D. Wirt, and the files and records of correspondence and appointments in charge of Mr. J. R. Walsh until his resignation on account of ill health, near the close of the year, when Miss Annie L. Arnold was assigned to the work.

DOCUMENTS AND STATIONERY.

The distribution of documents during the year has been large, owing to the great number of libraries designated under the act of January 12, 1895, to receive the publications of the Survey. Nearly 109,000 volumes of reports and over 26,000 geologic folios were distributed during the year, the postal authorities having handled this enormous number of packages promptly and without the loss of a single important piece. The distribution of the surplus copies of the office editions of the topographic maps was continued, as in previous years. There is a great demand for these maps, not only for general engineering and mining purposes, but also for use as road maps by cyclists and tourists.

The publications received and distributed embrace the Fifteenth Annual Report and chapters from the same, printed as separates; parts 2, 3, and 4 of the Sixteenth Annual Report, Bulletins Nos. 123, 124, 126, 128, 131, 132, 133, and 134, and geologic folios Nos. 13 and 15 to 25, besides the topographic sheets and other maps.

The proceeds from the sale of publications amounted to $1,220.85, a sum smaller than that of the previous year. This is due in part to the incorporation of the report on mineral resources into the Annual Report, which is not a sale publication, and in part to the fact that considerable material which under the former practice would have been printed in bulletin or monographic form and sold is now also being published in the Annual Report.

In the distribution of documents the wants of every applicant were carefully considered, and every document sent out was properly charged. Few, if any, of the books or maps are believed to have fallen into inappreciative hands, and duplication has been avoided.

With the growth of the Survey the demand for stationery and office supplies steadily increases, and the keeping up of the stock and filling of office requisitions now makes a heavy demand upon the time of the force of the section. During the year 480 requisitions for stationery and supplies were made upon the Department and about 2,700 office requisitions were filled.

Letters relating to documents, stationery, etc., to the number of 24,976 were received during the year, and 21,051 letters were sent.

CORRESPONDENCE AND RECORDS.

The register of general correspondence shows that 3,316 letters were briefed and indexed. These were referred or otherwise appropriately disposed of. The record of letters sent shows an aggregate of 3,365 pages of typewritten matter to have been press-copied. In addition to the care of the records of correspondence, the work embraced business connected with appointments and other changes in the force, and with leaves of absence and attendance. The appointment records show that appointments and other changes were made in the force during the year as follows: Original appointments, 33; appointments authorized by the Secretary, 45; renewals authorized by the Secretary, 11; promotions, 80; reduction, 1; resignations and dismissals, 23; transfers to other bureaus, 7; reinstatement, 1.

THE LIBRARY.

The library of the Survey was continued under the charge of Mr. Charles C. Darwin, assisted by Miss Julia L. McCord, Mr. Harry W. Meredith, and Mr. Thomas K. Gallaher.

Its total content in books, pamphlets, and maps has increased to 127,285 through accessions during the year of 2,140 books, 9,342 pamphlets, and 250 maps. Of these, 1,710 books, 2,000 pamphlets, and 200 maps were received as the result of exchange. The unusual increase in pamphlets results from a fortunate purchase of a valuable collection of 7,342 inaugural dissertations relating to chemistry, geography, geology, paleontology, and lithology. These were obtained in Leipsic, and were received in good order last March. Another noteworthy addition is a selection of 355 books and pamphlets from the remarkable and unique geological library of the late M. Gustave Cotteau, which was dispersed at public sale in Paris in 1895. This has enriched the library with some rare papers not before obtainable.

The growth of the library for the year is shown in detail in the following table:

CONTENTS OF THE LIBRARY, JUNE 30, 1896.

BOOKS.			
On hand June 30, 1895:			
Received by exchange	25,558		
Received by purchase	10,442		
		36,000	
Received during the past year:			
By exchange	1,710		
By purchase	430		
		2,140	
			38,140
PAMPHLETS.			
On hand June 30, 1895:			
Received by exchange	47,579		
Received by purchase	5,619		
		53,198	
Received during the past year:			
By exchange	2,000		
By purchase	7,342		
		9,342	
			62,540
MAPS.			
Geologic and topographic maps:			
On hand June 30, 1895		26,355	
Received during the year		250	
			26,605
Total number of books, pamphlets, and maps			127,285

The regular accessions have received proper author-entry. The large purchase of inaugural dissertations has compelled the temporary employment of another assistant, Miss Margaret Latimer, who is making good progress cataloguing them. With this exception the working force of the library remains the same as during the preceding year.

DIVISION OF DISBURSEMENTS AND ACCOUNTS.

This division has remained in charge of Mr. John D. McChesney, chief disbursing clerk. Summarized and detailed statements of disbursements follow.

FINANCIAL STATEMENT.

Amounts appropriated for and expended by the United States Geological Survey for the fiscal year ended June 30, 1896.

	Expenses Geological Survey 1896.	Expenses Geological Survey 1895–96.	Surveying lands Indian Territory 1895–96.	Engraving and printing the geological maps of the U. S. 1896.	Salaries, office of Geological Survey, 1896.	Total.
Appropriation for fiscal year 1895 and 1896—Acts approved March 2, 1895; February 26, 1896; April 25, 1896; and from other sources	$128, 918. 99	$250, 000. 00	$200, 000. 00	$65, 221. 76	$31, 390. 00	$675, 530. 75
Amounts expended, classified as follows:						
A. Services	103, 229. 84	172, 502. 28	119, 939. 18	47, 187. 83	31, 236. 20	474, 095. 33
B. Traveling expenses	4, 077. 67	16, 077. 26	2, 223. 85	45. 60	....	22, 424. 38
C. Transportation of property	324. 67	2, 781. 04	828. 85	13. 29	....	3, 947. 85
D. Field subsistence	683. 52	17, 327. 29	30, 941. 21	....	....	48, 952. 02
E. Field supplies and expenses	2, 423. 82	23, 031. 96	18, 136. 09	....	....	43, 591. 87
F. Field material	158. 00	2, 895. 38	19, 788. 85	....	....	22, 842. 23
G. Instruments	762. 20	1, 318. 95	6, 694. 46	....	....	8, 775. 61
H. Laboratory material	1, 313. 01	....	....	....	....	1, 313. 01
I. Photographic material	1, 881. 99	202. 31	7. 20	....	....	2, 091. 50
K. Books and maps	1, 053. 27	67. 50	....	....	....	1, 120. 77
L. Stationery and drawing material	142. 50	671. 86	485. 66	....	....	1, 300. 02
M. Illustrations for reports	1, 200. 85	....	....	....	....	1, 200. 85
N. Office rents	4, 499. 88	....	....	....	....	4, 499. 88
O. Office furniture	23. 50	409. 15	130. 00	....	....	562. 65
P. Office supplies and repairs	565. 21	666. 86	240. 74	....	....	1, 472. 81
Q. Storage	14. 71	428. 48	223. 75	....	....	666. 94
R. Correspondence	5. 00	16. 83	1. 50	....	....	23. 33
S. Materials for engraving and printing maps	....	....	....	6, 324. 45	....	6, 324. 45
T. Bonded railroad accounts settled at U.S. Treasury:						
Passenger	251. 01	1, 345. 55	....	....	....	1, 596. 56
Freight	....	273. 54	....	....	....	273. 54
Total expenditures	122, 610. 65	240, 016. 24	199, 641. 34	53, 571. 17	31, 236. 20	647, 075. 60
Balance unexpended July 1, 1896	6, 308. 34	9, 983. 76	358. 66	11, 650. 59	153. 80	28, 455. 15
Probable amount required to meet outstanding liabilities	6, 308. 34	9, 983. 76	358. 66	11, 650. 59	....	28, 301. 35

ANALYSIS OF DISBURSEMENTS.

Under the following heads appear the total expenditures under the various appropriations:

1.	Salaries, office of Geological Survey	$31, 236. 20
2.	Salarios of scientific assistauts	29, 900. 00
3.	Skilled laborers, and various temporary employees	12, 996. 78
4.	Topography	148, 743. 65
5.	Geology	91, 272. 59
6.	Paleontology	8, 937. 30
7.	Chemical and physical researches	8, 148. 01
8.	Preparation of illustrations	12, 747. 13
9.	Mineral resources of the United States	17, 941. 91
10.	Books for library, etc	1, 052. 71
11.	Gauging streams, etc	21, 816. 29
12.	Rent of office rooms	4, 499. 88
13.	Coal and gold resources of Alaska	4, 570. 64
14.	Engraving and printing geological maps of the United States	53, 571. 17
15.	Surveying lands in the Indian Territory	199, 641. 34
	Total	647, 075. 60

DETAILED STATEMENT OF EXPENDITURES.

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, from April 11, 1895, to June 30, 1896.

SALARIES, OFFICE OF GEOLOGICAL SURVEY.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount
1895.				
July 31	1	Pay roll of employees	Services, July, 1895	$2,643.60
Aug. 31	1	....do	Services, August, 1895	2,643.60
Sept. 30	1	....do	Services, September, 1895	2,543.91
Oct. 31	1	....do	Services, October, 1896	2,607.77
Nov. 12	1	Wm. M. Pippen	Services, Sept. 23 to Oct. 22, 1895.	48.91
30	2	Pay roll of employees	Services, November, 1895	2,560.30
Dec. 14	1	B. M. Doyle	Services, Dec. 1 to 11, 1895.	17.93
31	2	Pay roll of employees	Services, December, 1895	2,607.16
1896.				
Jan. 31	1	Pay roll of employees	Services, January, 1896	2,673.05
Feb. 29	1	....do	Services, February, 1896	2,494.81
Mar. 9	1	Samuel F. Harvey	Services, Mar. 1 to 9, 1896	11.87
31	2	Pay roll of employees	Services, March, 1896	2,551.71
Apr. 30	1	....do	Services, April, 1896	2,571.44
May 31	1	....do	Services, May, 1896	2,672.84
June 30	1	....do	Services, June, 1896	2,587.30
		Total		31,236.20

ENGRAVING AND PRINTING THE GEOLOGICAL MAPS OF THE UNITED STATES.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount
1895.				
July 1	1	Ross E. Gray	Services, July 1-5, 1895	$15.00
5	2	John Metzeroth	....do	16.25
31	3	James Callahan	Services, July 1-15, 1895	30.60
31	4	Pay roll of employees	Services, July, 1895	2,095.00
31	5	....do	....do	1,774.65
Aug. 12	1	Mutual Dist. Messenger Co	Burglar-alarm services	8.00
22	2	Fuchs & Lang Mfg. Co	Engravers' supplies	1.50
15	3	Pay roll of employees	Services, August, 1895	2,069.70
31	4	....do	....do	1,815.65
31	5	I. J. Martell	Services, Aug. 1-29, 1895	47.28
Sept. 12	1	L. H. Schneider's Son	Engravers' supplies	103.01
14	2	E. Sherwood Morgan	Electric motor	170.00
20	3	Department of the Interior	Engravers' supplies	27.18
23	4	Z. D. Gilman	....do	8.08
27	5	Ernest Kübel	Roulettes and electrotyping	478.60
9	6	Frederick J. Sherer	Services, Sept. 1-16, 1895	6.00
30	7	W. D. Evans	Services, September, 1895	97.80
30	8	Pay roll of employees	....do	1,888.13
30	9	....do	....do	1,618.80
Oct. 4	1	A. D. Farmer & Son Type Foundry Co.	Engravers' supplies	71.33
5	2	W. P. Robinson	Services, Sept. 1-30, 1895	58.80
10	3	C. & W. Pyle Co	Engravers' supplies	152.32
10	4	E. C. Fuller & Co	Stitching machine, etc	464.50
25	5	Lansburgh & Bro	Engravers' supplies	47.62
26	6	Hugh Riley	....do	2.20

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

ENGRAVING AND PRINTING THE GEOLOGICAL MAPS, ETC.—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
1895.					
Oct.	31	7	Paul A. Kuhnel	Services, Sept. 30, 1895	$2.50
	31	8	Walter D. Evans	Services, October, 1895	101.10
	31	9	Pay roll of employees	do	1,958.50
	31	10	do	do	1,862.10
Nov.	9	1	Department of the Interior	Engravers' supplies	167.50
	14	2	F. Wesel Mfg. Co	do	60.86
	14	3	W. D. Clark & Co	do	20.56
	23	4	W. A. Pate	do	42.00
	26	5	W. C. Newton & Co	do	40.84
	26	6	E. E. Jackson & Co	Bed block for press	8.00
	30	7	W. D. Evans	Services, November, 1895	97.80
	30	8	Pay roll of employees	do	1,898.00
	30	9	do	do	1,860.70
Dec.	7	1	Mackall Bros. & Flemer	Engravers' supplies	78.63
	9	2	R. Hoe & Co	do	24.26
	12	3	Robert Mayer & Co	do	33.48
	12	4	Harold E. Pine	Services, Dec. 1–12, 1895	7.50
	13	5	Department of the Interior	Supplies	31.70
	14	6	Ernest Kübel	Copper plates	267.75
	14	7	Mutual Dist. Messenger Co	Burglar-alarm service	24.00
	23	8	Geo. F. Muth & Co	Supplies	15.75
	28	9	S. J. Kübel	Traveling supplies	20.75
	31	10	Walter D. Evans	Services, December, 1895	101.10
	31	11	Pay roll of employees	do	1,958.50
	31	12	do	do	1,928.00
1896.					
Jan.	8	1	Adams Express Co	Freight charges	2.20
	8	2	U. S. Express Co	do	.25
	8	3	Geo. W. Knox Express Co	do	4.20
	8	4	Louis Gehlert	Supplies	15.00
	9	5	Shoemaker & Busch	do	30.58
	11	6	Bureau Engraving & Printing	Engraving on steel	14.70
	15	7	C. Schneider	Engraving supplies	.75
	15	8	H. Hoffa	do	73.25
	16	9	Department of the Interior	Supplies	501.12
	23	10	J. H. Chesley & Co	do	.98
	28	11	Woodward & Lothrop	do	3.00
	28	12	M. W. Beveridge	do	.14
	28	13	Ernest Kübel	Copper plates	267.75
	28	14	Bureau Engraving & Printing	Steel plate	6.65
	28	15	W. C. Newton & Co	Supplies	150.75
	28	16	Lansburgh & Bro	do	13.21
	28	17	Walter D. Evans	Services, January, 1896	102.20
	28	18	Pay roll of employees	do	1,878.60
	28	19	do	do	2,112.00
Feb.	14	1	Geo. F. Muth & Co	Engravers' supplies	.45
	14	2	Mackall Bros. & Flemer	do	13.02
	14	3	Lansburgh & Bro	do	96.89
	14	4	Burchard & Co	do	2.50
	14	5	Mutual Dist. Messenger Co	Burglar-alarm service	24.00
	15	6	Department of the Interior	Supplies	77.59
	18	7	Wm. D. Castle	do	4.85
	18	8	J. E. Hurley	Repairs	9.88
	18	9	Geo. Meier & Co	Lithographic stones	197.05
	20	10	W. B. Moses & Sons	Supplies	2.00
	20	11	W. A. Pate	do	24.88
	20	12	Thos. W. Smith	do	19.80
	21	13	Herman Baumgarten	Repairs	1.50

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

ENGRAVING AND PRINTING THE GEOLOGICAL MAPS, ETC.—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
1896					
Feb.	21	14	Robert Mayer & Co	Supplies	$13.75
	29	15	E. E. Jackson & Co	....do	13.86
	29	16	R. Hoe & Co	....do	30.39
	29	17	Walter D. Evans	Services, February, 1896	95.60
	29	18	Pay roll of employees	....do	1,757.80
	29	19	....do	....do	1,988.85
Mar.	7	1	Maurice Joyce Engraving Co.	Correcting block and making a type.	3.50
	7	2	L. H. Schneider's Son	Supplies	7.37
	11	3	Meyer Bros. Drug Co	....do	1.20
	12	4	Department of the Interior	....do	30.40
	13	5	E. C. Fuller & Co	....do	1.35
	13	6	Hugh Reilly	....do	1.40
	13	7	Mutual Dist. Messenger Co	Burglar-alarm services	8.00
	21	8	Shoemaker & Busch	Supplies	1.60
	23	9	W. A. Pate	....do	30.48
	21	10	Paul A. Kuhnel	Services, Mar. 1-20, 1896	30.00
	21	11	U. S. Express Co	Freight charges	2.38
	21	12	Adams Express Co	....do	2.15
	21	13	Geo. W. Knox Express Co	Freight charges and hauling	1.11
	31	14	Fuchs & Lang Mfg. Co	Supplies	4.75
	31	15	W. D. Evans	Services, March, 1896	102.20
	31	16	Pay roll of employees	....do	2,494.60
	31	17	....do	....do	1,375.80
Apr.	8	1	Ernest Kübel	Electrotyping bassos	272.10
	8	2	Z. D. Gilman	Supplies	1.00
	10	3	Mackall Bros. & Flemer	....do	41.52
	11	4	Shoemaker & Busch	....do	3.44
	8	5	Z. D. Gilman	....do	.70
	10	6	Department of the Interior	....do	481.68
	10	7	Chas. A. Muddiman	Gas stoves	6.15
	8	8	U. S. Express Co	Freight charges	1.00
	22	9	J. H. Chesley & Co	Supplies	.96
	24	10	Hugh Reilly	....do	1.40
	25	11	Harry C. Jones	Engraved blocks	24.08
	30	12	Andrew B. Graham	Photolithographic transfers	25.20
	30	13	Ernest Kübel	Supplies	17.38
	30	14	Benj. S. Stewart	Services, Apr. 24, 30, 1896	9.00
	30	15	W. D. Evans	Services, April, 1896	98.90
	30	16	Pay roll of employees	....do	2,390.95
	30	17	....do	....do	1,440.75
May	6	1	Ernest Kübel	Copper plates	267.75
	6	2	J. H. Chesley & Co	Supplies	3.93
	6	3	W. C. Newton & Co	....do	87.44
	6	4	Mackall Bros. & Flemer	....do	19.43
	11	5	Mutual Dist. Messenger Co	Burglar-alarm service	8.00
	13	6	Shoemaker & Busch	Supplies	1.44
	13	7	The Celluloid Co	....do	85.00
	16	8	Chas. Hellmuth	....do	15.00
	16	9	Thos. W. Smith	....do	106.00
	18	10	Z. D. Gilman	....do	2.58
	18	11	Department of the Interior	....do	26.90
	19	12	Geo. F. Muth & Co	....do	3.04
	22	13	Wm. D. Clark & Co	....do	32.69
	26	14	Wm. D. Castle	Supplies and repairs	18.40
	29	15	Lansburgh & Bro	....do	3.60
	29	16	W. D. Evans	Services, May, 1896	102.20
	29	17	Pay roll of employees	....do	2,409.57
	29	18	Pay roll of employees	....do	1,461.65

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

ENGRAVING AND PRINTING THE GEOLOGICAL MAPS, ETC.—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
1896					
June	6	1	Andrew B. Graham	Photolithographing maps	$14.00
	9	2	Department of the Interior	Supplies	102.15
	12	3	S. J. Kuhl	Traveling expenses	24.85
	13	4	H. Hoffa	Supplies	18.00
	20	5	Mackall Bros. & Flemer	.....do	19.43
	20	6	Melville Lindsay	.....do	5.50
	20	7	Mutual Dist. Messenger Co	Services	8.00
	20	8	Ernest Kübel	Machinery, etc	517.75
	15	9	Thomas Solau	Services, June 1-15, 1896	10.00
	26	10	John C. Parker	Supplies	31.50
	30	11	Shoemaker & Busch	.....do	37.80
	30	12	Geo. F. Muth & Co	.....do	15.00
	30	13	W. D. Evans	Services, June, 1896	98.90
	30	14	Pay roll of employees	.....do	2,339.35
	30	15	.....do	.....do	1,468.25
			Total		53,571.17

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896.

JULY, 1895.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
July	18	1	L. H. Taylor	Services, July 1-3, 1895	$16.00
	18	2	Cyrus C. Babb	Services, July 1-15, 1895	66.00
	18	3	F. H. Newell	Field services	69.65
	18	4	Chas. L. Conditt	Publication	7.50
	19	5	B. F. Phillips	Services, July 1-6, 1895	7.74
	18	6	Florence Pollock	Services, July 1-9, 1895	16.00
	18	7	Charles E. Munroe	Analyses of rocks	48.00
	22	8	A. M. Ryon	Services, July 1-6, 1895	30.00
	22	9	W. G. Purssell	Services, July 1-16, 1895	78.00
	22	10	Elwood Mead	Services, July 1-18, 1895	90.00
	25	11	Philadelphia & Reading R.R.	Transportation of assistant	30.30
	24	12	Frances Wieser	Drawings	105.00
	25	13	G. K. Gilbert	Traveling expenses	41.00
	31	14	C. C. Willard	Rent of office rooms, July, '95	349.99
	31	15	C. Kirchhoff	Services, July, 1895	135.00
	31	16	James M. Swank	.....do	135.00
	31	17	T. M. Stanton	.....do	132.06
	31	18	F. Berger	.....do	80.00
	31	19	L. P. Bush	.....do	65.00
	31	20	Bailey Willis	.....do	252.70
	31	21	R. U. Goode	.....do	210.60
	31	22	Gilbert Thompson	.....do	168.50
	31	23	Frank Burns	.....do	50.50
	31	24	Pay roll of employees	.....do	901.10
	31	25	.....do	.....do	817.10
	31	26	.....do	.....do	1,042.27
	31	27	.....do	.....do	336.90
	31	28	.....do	.....do	471.70
	31	29	.....do	.....do	850.70
	31	30	.....do	.....do	1,080.10
	31	31	.....do	.....do	558.63
	31	32	Marvin J. Welch	.....do	25.50
			Total		8,268.84

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

AUGUST, 1895.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Aug.	3	1	G. N. Saegmuller	Instruments and repairs	$190.00
	3	2	do	do	100.00
	8	3	G. K. Gilbert	Field expenses	57.86
	6	4	W. T. Griswold	Services, July, 1895	168.50
	9	5	A. P. Davis	Traveling expenses	87.50
	9	6	do	Field expenses	82.20
	9	7	F. H. Newell	do	35.00
	10	8	Cyrus C. Babb	Traveling expenses	36.20
	9	9	G. F. Sherman	Services, July 15–Aug. 1, '95.	96.00
	9	10	D. C. Humphreys	Services, July 22–Aug. 3, '95.	72.00
	13	11	W. G. Russell	Services, July 18–31, 1895	72.00
	13	12	A. M. Ryon	Services, July 19–24, 1895	30.00
	14	13	J. B. Lippincott	Services, July 6–16, 1895	59.50
	14	14	P. E. Harroun	Services, July 1–22, 1895	96.00
	14	15	do	Services, July 23–Aug. 2, '95.	60.00
	14	16	O. V. P. Stout	Services, July 2–17, 1895	75.00
	13	17	G. K. Gilbert	Field expenses	48.76
	13	18	T. W. Stanton	do	25.76
	13	19	Henry Romeike	Press clippings	8.12
	14	20	Edgar A. Werner	Publications	16.25
	15	21	Fred J. Lung	Record case	125.00
	15	22	De Lancey W. Gill	Traveling expenses	22.20
	12	23	Adams Express Co	Freight charges	5.70
	20	24	John S. Arndt	Report	10.00
	19	25	Cyrus C. Babb	Field expenses	41.25
	21	26	James B. Lambie	Supplies	51.80
	21	27	Wm. A. Raborg	Traveling expenses	3.75
	23	28	H. O. Hofman	Tests of fire clay	15.00
	26	29	John Reynolds	Services, July 20–26, 1895	9.00
	26	30	Eugene Cobb	do	9.00
	26	31	Wm. C. Day	Services, July 1–Aug. 10, '95.	175.00
	26	32	Fillmore Cogswell	Services, July 8–18, 1895	60.00
	26	33	E. C. Murphy	Services, July 12–27, 1895	81.00
	26	34	L. H. Taylor	Services, July 10–Aug. 13, '95	48.00
	26	35	P. E. Harroun	Services, Aug. 5–14, 1895	54.00
	26	36	J. S. J. Lallie	Repairs to meters	39.70
	26	37	W. T. Galliher	Supplies	91.86
	26	38	F. H. Newell	Field expenses	26.00
	26	39	do	do	9.00
	26	40	Stephenson's Express	Hauling laboratory material	18.00
	24	41	U. S. Express Co	Freight charges	.80
	31	42	C. C. Willard	Rent of office rooms, Aug., '95	349.99
	31	43	L. P. Bush	Services, August, 1895	65.00
	31	44	Jno. R. Hudson	do	60.60
	31	45	W. T. Griswold	do	168.50
	31	46	Gilbert Thompson	do	168.50
	31	47	R. U. Goode	do	210.60
	31	48	Bailey Willis	do	252.70
	31	49	Pay roll of employees	do	901.40
	31	50	do	do	817.10
	31	51	do	do	995.00
	31	52	do	do	400.90
	31	53	do	do	471.70
	31	54	do	do	909.70
	31	55	do	do	1,061.00
	31	56	do	do	607.60
			Total		9,756.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

SEPTEMBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 9	1	T. W. Stanton	Services, August, 1895	$134.80
9	2	F. H. Newell	Traveling expenses	48.85
9	3	.....do	Field expenses	23.00
9	4	.....do	.....do	11.00
9	5	Cyrus C. Babb	.....do	52.95
10	6	.....do	.....do	25.80
9	7	G. K. Gilbert	.....do	262.93
9	8	.....do	Traveling expenses	14.80
10	9	J. Jardine	Services, July and Aug., 1895	6.00
10	10	J. L. Prentiss	.....do	10.00
10	11	S. P. Brown	.....do	6.00
10	12	Henry V. Smith	.....do	14.00
10	13	Frank Jacobs	.....do	6.00
10	14	John Murdock	.....do	10.00
10	15	J. S. Regan	.....do	15.00
10	16	J. N. Lane	.....do	6.00
10	17	R. L. Holder	.....do	6.00
10	18	Frank Roper	.....do	6.00
10	19	T. F. Burke	.....do	6.00
10	20	Chas. S. Davis	.....do	6.00
10	21	Frank Adair	.....do	6.00
10	22	J. H. Schofield	.....do	6.00
10	23	R. N. Gill	.....do	6.00
10	24	George Robertson	.....do	6.00
10	25	Mary D. Smith	.....do	6.00
10	26	B. W. Vedder	.....do	6.00
10	27	J. P. Lippencott	Services, July 22-31, 1895	63.00
10	28	.....do	Services, Aug. 1-16, 1895	98.00
10	29	W. G. Russell	Services, Aug. 1-20, 1895	99.00
10	30	O. V. Stout	Services, Aug. 6-28, 1895	117.00
10	31	P. E. Herroun	Services, Aug. 15-31, 1895	90.00
10	32	L. H. Taylor	Services, Aug. 17-25, 1895	48.00
10	33	D. C. Humpheys	Services, Aug. 20-31, 1895	66.00
11	34	Francis Weiser	Original drawings	105.45
11	35	S. A. Newberry	Report on cement	50.00
11	36	L. H. Schneider's Son	Supplies	15.60
11	37	Leon Sloss, agent	Transportation of assistants	111.50
11	38	St. L. & San Fran. R. R. Co	.....do	24.50
14	39	A. P. Davis	Field expenses	175.70
14	40	.....do	Traveling expenses	92.60
14	41	Lester F. Ward	.....do	106.80
14	42	Geo. H. Girty	.....do	16.10
14	43	.....do	Field expenses	2.50
21	44	Mary Bryant	Services, Sept. 1-16, 1895	7.83
20	45	T. W. Stanton	Traveling expenses	109.60
20	46	Department of the Interior	Illustration supplies	199.37
20	47	.....do	Paleontologic supplies	1.20
23	48	Z. D. Gilman	Supplies	79.07
27	49	D. McRae	Boxing and hauling specimens.	5.00
25	50	N. H. Darton	Traveling expenses	40.53
30	51	F. H. Newell	Field expenses	21.00
30	52	.....do	.....do	49.74
30	53	J. V. Lewis	Services, Aug. 1-20, 1895	99.00
30	54	Fillmore Cogswell	Services, Aug. 26-31, 1895	33.00
30	55	A. M. Ryon	Services, Sept. 2-9, 1895	42.00
30	56	P. E. Harroun	Services, Sept. 2-10, 1895	48.00
30	57	John Birkinbine	Traveling expenses	103.43

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

SEPTEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 30	58	Wm. C. Douglass	Services, Sept. 2–5, 1895	$6.00
30	59	Cyrus C. Babb	Services, September, 1895	97.80
30	60	Bailey Willis	do	244.60
30	61	R. U. Goode	do	203.80
30	62	Gilbert Thompson	do	163.00
30	63	W. T. Griswold	do	163.00
30	64	Pay roll of employees	do	872.20
30	65	do	do	790.80
30	66	do	do	1,030.11
30	67	do	do	556.60
30	68	do	do	456.60
30	69	do	do	802.39
30	70	do	do	977.50
30	71	do	do	492.00
		Total		9,667.05

OCTOBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Oct. 2	1	N. American Commercial Co.	Board and lodging, etc	$958.88
2	2	do	Transportation of assistants	300.00
2	3	do	Board and lodging	48.00
2	4	do	Hire of transportation	75.00
2	5	Joseph D. Weeks	Services, July 1–Sept. 14, '95.	330.00
2	6	R. R. Gurley	Traveling expenses	80.21
2	7	Oreg., S. L. & U. N. Rwy	Transportation of assistants	26.55
4	8	Filmore Cogswell	Field material	18.25
4	9	C. C. Willard	Rent of office rooms, Sept., '95	349.99
4	10	Francis Wieser	Original drawings	66.70
4	11	F. H. Newell	Field expenses	30.00
4	12	U. S. Express Co	Freight charges	5.80
10	13	Robert Beall	Publications	25.75
10	14	L. P. Bush	Services, Sept. 1–30, 1895	65.00
10	15	Fred F. B. Coffin	Services, Sept. 16–30, 1895	50.00
10	16	John Birkinbine	Services, July 1–Sept. 30, '95.	395.00
11	18	Wm. H. Dall	Traveling expenses	92.64
11	19	Chester W. Purrington	do	87.76
10	20	Southern Pacific Co	Transportation of assistants	10.35
10	21	Northern Pacific R. R. Co	do	48.95
12	22	Cyrus C. Babb	Traveling expenses	88.10
12	23	do	Field expenses	109.15
12	24	G. K. Gilbert	Traveling expenses	3.25
12	25	do	Field expenses	2.00
12	26	do	do	210.77
14	27	N. H. Darton	do	109.45
14	28	Oreg. Rwy. & Navigation Co	Transportation of assistants	6.91
14	29	Adams Express Co	Freight charges	13.15
14	30	T. Wayland Vaughan	Traveling expenses	64.30
25	31	Department of the Interior	Illustration supplies	1.62
25	32	Herman Baumgarten	do	11.60
25	33	Fred. J. Lung	do	23.50
25	34	James B. Lambie	Supplies	13.75
25	35	F. H. Newell	Field expenses	12.00
25	36	do	do	16.00
25	37	do	do	12.00
26	38	E. C. Murphy	Services, Sept. 4–14, 1895	60.00
28	39	A. P. Davis	Traveling expenses	80.65

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

OCTOBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Oct. 28	40	A. P. Davis	Traveling expenses	$71.85
28	41	.....do	Field expenses	33.70
28	42	.....do	.....do	33.15
28	43	J. B. Lippincott	Services, Aug. 23–31, 1895	56.00
28	44	.....do	Services, Sept. 2–30, 1895	175.00
28	45	.....do	Services, Oct. 1–21, 1895	126.00
29	46	J. D. Bush	Services, July 1, Aug. 31, '95	6.00
29	47	D. C. Humphreys	Services, Sept. 2–12, 1895	57.00
29	48	Samuel Fortier	Services, Sept. 7–23, 1895	90.00
29	49	O. V. P. Stout	Services, Sept. 16–26, 1895	60.00
29	50	W. G. Russell	Services, Sept. 20–Oct. 12, '95	62.00
28	51	Geo. H. Girty	Traveling expenses	45.88
28	52	.....do	Field expenses	3.67
29	53	Missouri Pacific Rwy. Co	Transportation of assistant	3.00
31	54	F. H. Newell	Field expenses	15.00
31	55	Cyrus C. Babb	.....do	31.40
31	56	N. H. Darton	Traveling expenses	124.70
31	57	Fred F. B. Coffin	.....do	41.80
31	58	.....do	.....do	15.10
31	59	C. C. Willard	Rent of office rooms Oct., '95	349.99
31	60	F. B. Scott	Services, October, 1895	50.50
31	61	Geo. H. Eldridge	.....do	227.40
31	62	R. U. Goode	.....do	210.60
31	63	Gilbert Thompson	.....do	168.50
31	64	W. T. Griswold	.....do	168.50
31	65	Pay roll of employees	.....do	926.70
31	66	.....do	.....do	817.10
31	67	.....do	.....do	1,055.60
31	68	.....do	.....do	579.70
31	69	.....do	.....do	471.70
31	70	.....do	.....do	777.61
31	71	.....do	.....do	1,019.50
31	72	.....do	.....do	607.60
		Total		12,385.31

NOVEMBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Nov. 7	1	David T. Day	Traveling expenses	$16.45
7	2	.....do	.....do	24.65
9	3	Cyrus C. Babb	.....do	91.79
9	4	.....do	Field expenses	78.60
9	5	F. H. Newell	.....do	25.52
9	6	.....do	.....do	35.00
9	7	.....do	.....do	26.00
9	8	.....do	.....do	26.00
9	9	G. F. Sherman	Services, Sept. 5–7, 1895	18.00
9	10	L. H. Taylor	Services, Sept. 5–30, 1895	54.00
9	11	A. M. Ryon	Services, Sept. 28–Oct. 7, '95	25.40
9	12	Porter J. Preston	Services, Oct. 7–11, 1895	23.00
9	13	Fillmore Cogswell	Services, Oct. 4–15, 1895	57.00
9	14	E. S. Ritchie & Sons	Repairs	48.50
9	15	Francis Weiser	Drawings	27.20
9	16	Meyer Bros. Drug Co	Illustration supplies	3.78
9	17	F. Lymond Garrison	Report	25.00
9	18	Department of the Interior	Supplies	5.31
11	19	L. P. Bush	Services, October, 1895	65.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

NOVEMBER, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Nov. 11	20	P. E. Harroun	Services, Sept. 13-30, 1895	$90.00
11	21	W. & L. E. Gurley	Instruments	300.00
11	22	Charles E. Munroe	Assay of ores	15.75
11	23	Schoemaker & Busch	Laboratory supplies	10.20
11	24	.....do	.....do	2.48
11	25	.....do	Illustration supplies	68.78
11	26	.....do	.....do	129.58
12	27	Baltimore & Ohio R. R. Co	Freight charges	1.74
12	28	Bur. & Mo. Riv. R. R. in Nebr.	Transportation of assistant	19.70
13	29	J. L. Prentiss	Services, Sept. and Oct., '95	10.00
13	30	James Storrs	Services with outfit	57.00
13	31	.....do	.....do	87.00
14	32	N. H. Darton	Field expenses	53.50
14	33	.....do	Traveling expenses	104.95
14	34	J. V. Lewis	Services, Sept. 2-20, 1895	102.00
14	35	J. S. Reagan	Services, Sept. and Oct., 1895	15.00
14	36	Fred F. B. Coffin	Services, October, 1895	100.00
14	37	Thomas Somerville & Sons	Supplies and repairs	4.60
14	38	Wm. D. Clark & Co	Illustration supplies	1.00
15	39	Baltimore & Ohio R. R. Co	Transportation of assistant	46.30
15	40	Pennsylvania R. R. Co	.....do	11.50
15	41	S. P. Brown	Services, September, 1895	3.00
15	42	J. H. Schofield	Services, Sept. and Oct., 1895	6.00
15	43	Frank Adair	.....do	6.00
15	44	George Robertson	.....do	6.00
15	45	John Davis	.....do	6.00
15	46	F. F. Burke	.....do	6.00
15	47	Mary D. Smith	.....do	6.00
15	48	R. L. Holder	.....do	6.00
15	49	J. N. Lane	.....do	6.00
15	50	Frank Roper	.....do	6.00
15	51	B. W. Vedder	.....do	6.00
15	52	J. D. Bush	.....do	6.00
18	53	Elwood Mead	Services, Aug. 1-12, 1895	70.00
18	54	.....do	Services, Sept. 25-27, 1895	21.75
18	55	.....do	Services, Oct. 18-23, 1895	37.25
18	56	F. H. Newell	Field expenses	9.00
18	57	.....do	.....do	9.00
19	58	.....do	.....do	50.00
19	59	Samuel Fortier	Services, Oct. 12-16, 1895	24.60
19	60	G. F. Sherman	Services, Oct. 16-24, 1895	43.75
19	61	P. E. Harroun	Services, Oct. 15-31, 1895	86.00
19	62	R. N. Gill	Services, Sept. and Oct., 1895	6.00
20	63	F. H. Newell	Traveling expenses	155.80
20	64	Cyrus C. Babb	Field expenses	48.65
19	65	Henry Romeike	Clippings, August, September, and October, 1895.	21.40
20	66	Heinrich Reis	Report on clay industry	50.00
20	67	F. H. Newell	Field expenses	21.83
21	68	Fred F. B. Coffin	Traveling expenses	64.70
16	69	Alpheus Hyatt	Services, Sept. and Oct., 1895	150.00
23	70	Z. D. Gilman	Supplies	103.25
26	71	E. E. Jackson & Co	.....do	12.74
23	72	Richard M. Webster	Services, Nov. 1-10, 1895	24.46
30	73	S. F. Peckman	Report on petroleum	50.00
30	74	C. Kirchhoff	Report on copper, etc	415.00
30	75	H. Gibb	Services, November, 1895	70.00
30	76	L. P. Bush	.....do	65.00
30	77	W. T. Griswold	.....do	163.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

NOVEMBER, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Nov. 30	78	Geo. H. Eldridge	Services, November, 1895	$220.20
30	79	Pay roll of employees	......do	2,054.20
30	80	......do	......do	1,023.80
30	81	......do	......do	506.60
30	82	......do	......do	456.60
30	83	......do	......do	831.60
30	84	......do	......do	1,104.50
30	85	......do	......do	539.38
30	86	C. C. Willard	Rent of office rooms, Nov., '95	349.99
30	87	E. J. Pullman	Illustration supplies	92.69
		Total		10,929.52

DECEMBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Dec. 3	1	Wm. C. Day	Services, Aug. 12–Nov. 30, '95	$480.00
4	2	A. C. Peale	Services, Nov. 25–30, 1895	30.00
7	3	Mackall Bros. & Flemer	Supplies	151.71
7	4	Stephenson's Express	Freight and hauling	35.71
7	5	......do	......do	6.78
7	6	G. K. Gilbert	Field expenses	204.48
7	7	......do	Traveling expenses	59.15
9	8	Baltimore & Ohio R. R. Co.	Transportation of assistants	37.10
9	9	Oreg. S. L. & U. N. Ry. Co.	......do	28.70
9	10	W. G. Russell	Services, Nov. 1–15, 1895	75.00
9	11	Fillmore Cogswell	Services, Nov. 16–26, 1895	42.00
9	12	J. B. Lippincott	Services, November, 1895	182.00
9	13	Fred F. B. Coffin	......do	100.00
9	14	J. S. J. Lallie	Supplies, etc	17.31
10	15	Smithsonian Institution	Transportation of exchanges	57.50
10	16	John Mitchell	Repairing sink	6.60
10	17	Chas. E. Munroe	Assay of ores	5.00
10	18	Chic., St. P., M. & O. Rwy. Co	Transportation of assistants	18.78
12	19	F. H. Newell	Field expenses	15.00
12	20	Jefferson Middleton	Traveling expenses	26.10
12	21	Henry Romeike	Press clippings	5.40
13	22	Department of the Interior	Illustration supplies	166.50
13	23	Charles E. Munroe	Analyses of coals	76.50
13	24	Bur. & Mo. Riv. R. R. in Nebr.	Transportation of assistants	6.35
14	25	W. H. Loudermilk	Publications	40.00
17	26	Joseph D. Weeks	Services, Sept. 16–Nov. 5, '95	220.00
17	27	R. R. Gurley	Services, Nov. 1–5, 1895	16.00
17	28	G. N. Saegmueller	Repairs	11.25
17	29	Fred F. B. Coffin	Traveling expenses	72.05
18	30	D. C. Humphreys	Services, Oct. 1–Nov. 2, 1895	12.50
18	31	F. H. Newell	Field expenses	12.00
19	32	Library Bureau	Library supplies	33.40
20	33	E. W. Parker	Traveling expenses	9.40
21	34	Chicago & N. W. Rwy. Co	Transportation of assistants	54.11
21	35	Fremont. Elk. & Mo. Val. Rwy	......do	18.00
21	36	Alpheus Hyatt	Services, November, 1895	50.00
21	37	Wm. C. Day	Services, Dec. 2–14, 1895	60.00
21	38	Samuel Fortier	Services, Nov. 4–12, 1895	25.60
21	39	P. E. Harroun	Services, Nov. 4–30, 1895	144.00
21	40	E. C. Murphy	Services, Oct. 2–Nov. 14, 1895	42.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

DECEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Dec. 21	41	F. H. Newell	Field expenses	$58.00
21	42	.....do	.....do	25.00
21	43	.....do	.....do	42.50
21	44	.....do	.....do	49.50
21	45	.....do	.....do	87.00
23	46	L. H. Taylor	Services, Nov. 5-8, 1895	24.00
23	47	Geo. F. Muth & Co	Supplies	35.93
31	48	Leon Sloss, agent	Transportation of assistants	57.00
31	49	Chas. E. Munroe	Analyses of coal	63.00
31	50	C. C Willard	Rent of office rooms, Dec., '95	349.99
31	51	Altha T. Coons	Services, December, 1895	52.00
31	52	H. Gibb	.....do	70.00
31	53	L. P. Bush	.....do	65.00
31	54	Pay roll of employees	.....do	2,518.80
31	55	.....do	.....do	1,055.60
31	56	.....do	.....do	521.70
31	57	.....do	.....do	471.70
31	58	.....do	.....do	775.00
31	59	.....do	.....do	927.50
31	60	.....do	.....do	660.14
31	61	.....do	.....do	421.20
		Total		10,984.51

JANUARY, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Jan. 4	1	Robert Beall	Publications	$85.10
7	2	J. B. Lippincott	Services, December, 1895	175.00
8	3	U. S. Express Co	Freight charges	70.02
8	4	Adams Express Co	.....do	16.61
9	5	Geo. W. Knox Express Co	Freight charges and hauling	2.08
9	6	Shoemaker & Busch	Laboratory supplies	1.80
9	7	.....do	Laboratory and illustration supplies.	24.05
9	8	H. H. Fish	Hire of transportation	57.00
9	9	A. M. Ryon	Services, Nov. 29-Dec. 14, '95	28.00
9	10	P. E. Harroun	Services, Dec. 11-21, 1895	56.00
9	11	F. Cogswell	Services, Dec. 23-27, 1895	21.00
9	12	Burr Bossell	Services, Dec. 23-31, 1895	28.00
10	13	A. P. Davis	Field expenses	18.05
10	14	F. H. Newell	.....do	26.00
10	15	.....do	.....do	45.58
10	16	.....do	.....do	12.00
10	17	.....do	.....do	50.00
10	18	.....do	.....do	33.00
10	19	Julius Bien & Co	Publications	30.00
11	20	Deverenx & Gaghan	Repairs	20.85
15	21	F. H. Newell	Field expenses	17.00
15	22	.....do	.....do	19.00
15	23	.....do	.....do	17.00
15	24	.....do	.....do	36.90
15	25	.....do	.....do	10.00
15	26	.....do	.....do	26.00
15	27	.....do	.....do	15.00
15	28	Cyrus C. Babb	.....do	114.35
15	29	B. M. Hall	Services, Dec. 13-23, 1895	10.00
15	30	Samuel Fortier	Services, Dec. 9-12, 1895	21.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

JANUARY, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Jan. 15	31	G. F. Sherman	Services, Dec. 10-14, 1895	$31.25
15	32	L. H. Taylor	Services, Dec. 24-31, 1895	43.00
15	33	W. G. Russell	Services, Dec. 4-31, 1895	138.00
15	34	R. R. Bowker	Publications	5.00
15	35	L. P. Siebold	Freight, etc	4.35
15	36	James M. Swank	Services, Nov. 18-Dec., 1895	165.00
16	37	Wm. C. Day	Services, Dec. 16, 1895-Jan. 15, 1896.	125.00
16	38	D. C. Humphreys	Services, Dec. 26-28, 1895	15.00
16	39	Department of the Interior	Supplies	106.09
16	40	do	do	19.81
16	41	do	do	1.00
18	42	Royce & Marean	do	24.50
18	43	Missouri Pacific Rwy. Co	Freight	1.10
20	44	Herman Baumgarten	Supplies	4.05
23	45	Charles E. Munroe	Assay of ores	22.00
23	46	American Journal of Science	Publications	6.75
23	47	David T. Day	Traveling expenses	24.08
25	48	E. W. Parker	do	105.60
28	49	M. W. Beveridge	Laboratory supplies	.95
28	50	Southern Pacific Co	Transportation of assistants	27.20
31	51	J. Schultzbach	Supplies	30.50
31	52	Chas. E. Munroe	Analyses of coal	4.50
31	53	W. Andrew Boyd	Publications	25.00
31	54	C. C. Willard	Rent of office rooms, Jan., '96.	349.99
31	55	H. Gibb	Services, January, 1896	70.00
31	56	L. P. Bush	do	65.00
31	57	Altha T. Coons	do	54.00
31	58	Pay roll of employees	do	2,546.30
31	59	do	do	1,066.50
31	60	do	do	477.00
31	61	do	do	477.00
31	62	do	do	783.50
31	63	do	do	1,046.10
31	64	do	do	808.20
31	65	do	do	425.90
		Total		10,185.61

FEBRUARY, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Feb. 4	1	W. F. Hillebrand	Traveling expenses	$16.60
5	2	Robert Beall	Publications	33.10
7	3	P. E. Hatroun	Services, Jan. 9-30, 1896	114.00
7	4	J. B. Lippincott	Services, Jan. 2-31, 1896	182.00
7	5	Cyrus C. Babb	Traveling expenses	117.85
7	6	F. H. Newell	Field expenses	26.00
7	7	do	do	26.00
7	8	do	do	26.00
7	9	do	do	61.67
7	10	do	do	25.00
7	11	A. C. Peale	Services, Jan. 21-31, 1896	60.00
7	12	F. H. Willis	Report	25.00
7	13	Baker & Co	Laboratory supplies	38.61
7	14	do	do	19.61
7	15	Henry Romeike	Press clippings	11.52
7	16	Shoemaker & Busch	Supplies	62.97

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

FEBRUARY, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Feb.	12	17	Chic., St. P., M. & O. Rwy. Co	Transportation of assistant.	$7.30
	12	18	B. M. Hall	Services, Jan. 15–29, 1896	28.00
	14	19	Mackall Bros. & Flemer	Illustration supplies	42.22
	14	20	Geo. F. Muth & Co	Supplies	12.55
	14	21	E. F. Brooks Co	....do	3.00
	14	22	W. G. Russell	Services, Jan. 13–31, 1896	78.00
	14	23	G. F. Sherman	Services, Jan. 23–31, 1896	49.00
	14	24	D. C. Humphreys	Services, Jan. 24–31, 1896	30.00
	15	25	Department of the Interior	Supplies	44.28
	15	26	....do	....do	1.92
	17	27	Wm. C. Day	Traveling expenses	10.21
	17	28	....do	Services, Jan. 16–Feb. 15,'96	135.00
	18	29	John Birkinbine	Services, November, 1895	100.00
	18	30	Jno. C. Parker	Publications	179.75
	18	31	M. W. Beveridge	Illustration supplies	3.23
	20	32	Shoemaker & Busch	....do	49.18
	21	33	Herman Baumgarten	Gauging streams and supplies.	10.65
	21	34	Z. D. Gilman	Supplies	111.60
	18	35	Smithsonian Institution	Transportation of exchanges	30.30
	27	36	E. W. Parker	Traveling expenses	45.70
	29	37	David T. Day	....do	34.26
	29	38	John C. Parker	Supplies	3.75
	29	39	E. E. Jackson & Co	....do	18.10
	29	40	Edward Kübel	Repairs	29.50
	29	41	Thomas W. Smith	Supplies	2.50
	29	42	C. C. Willard	Rent of office rooms, Feb.,'96	349.99
	29	43	H. Gibb	Services, February, 1896	70.00
	29	44	L. P. Bush	....do	65.00
	29	45	Pay roll of employees	....do	2,382.40
	29	46	....do	....do	1,002.00
	29	47	....do	....do	416.00
	29	48	....do	....do	446.00
	29	49	....do	....do	733.00
	29	50	....do	....do	967.80
	29	51	....do	....do	743.78
	29	52	....do	....do	460.70
			Total		9,572.60

MARCH, 1896.

Mar.	5	1	Robert Beall	Publications	$48.75
	7	2	Henry Romeike	Press clippings	5.72
	7	3	L. H. Schneider's Son	Supplies	10.09
	7	4	Thos. Somerville & Sons	....do	5.20
	7	5	Baker & Co	Repairs	48.10
	10	6	G. F. Becker	Traveling expenses	101.58
	11	7	Meyer Bros. Drug Co	Illustration supplies	3.15
	12	8	Department of the Interior	....do	4.32
	12	9	....do	Mineral resource supplies	23.25
	12	10	R. R. Bowker	Publications	3.50
	12	11	J. A. Udden	Services, Nov. 11–23, 1895	30.00
	13	12	L. H. Taylor	Services, Jan. 7–Feb., 1896	96.25
	13	13	P. E. Harroun	Services, Feb. 13–20, 1896	39.00
	13	14	W. G. Russell	Services, Feb. 10–15, 1896	36.00
	13	15	D. C. Humphreys	Services, Feb. 10–29, 1896	48.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

MARCH, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Mar. 12	16	J. B. Lippincott	Services, Feb. 1-29, 1896	$140.00
13	17	G. F. Sherman	Services, Feb. 29, 1896	5.00
12	18	F. H. Newell	Field expenses	37.00
13	19	....do	....do	22.00
13	20	....do	....do	49.00
13	21	....do	....do	20.00
13	22	....do	....do	55.13
13	23	....do	....do	58.00
14	24	....do	....do	25.50
14	25	....do	....do	53.70
14	26	....do	....do	42.50
14	27	Mackall Bros. & Flemer	Laboratory supplies	8.95
14	28	F. W. Clarke	Traveling expenses	28.50
21	29	F. H. Newell	Field expenses	33.90
21	30	....do	....do	58.11
21	31	....do	....do	54.00
21	32	....do	....do	13.80
21	33	....do	....do	54.50
21	34	Shoemaker & Busch	Laboratory supplies	8.85
21	35	David T. Day	Traveling expenses	54.45
21	36	Altha T. Coons	Services, February, 1896	50.00
21	37	W. C. Day	Services, Feb. 17-Mar. 14, 1896.	120.00
23	38	C. J. Norwood	Services, January, 1896	30.00
23	39	L. P. Siebold	Freight storage and custom charges.	16.92
21	40	U. S. Express Co	Freight charges	23.29
21	41	Adams Express Co	....do	34.91
21	42	Geo. W. Knox Express Co	Freight charges and hauling	5.72
31	43	Stephenson's Express	....do	1.12
31	44	F. H. Newell	Field expenses	21.00
31	45	Wm. A. Wansleben	Preparation of maps	50.00
31	46	Wm. C. Day	Traveling expenses	13.38
31	47	....do	....do	12.83
31	48	P. J. Ryon	Supplies	4.00
31	49	Shoemaker & Busch	....do	37.21
31	50	R. R. Bowker	Publications	3.50
31	51	Robert Beall	....do	53.60
31	52	C. C. Willard	Rent of office rooms Mar., '96	349.99
31	53	H. Gibb	Services, March, 1896	70.00
31	54	L. P. Bush	....do	65.00
31	55	Pay roll of employees	....do	2,546.30
31	56	....do	....do	1,066.50
31	57	....do	....do	527.00
31	58	....do	....do	477.00
31	59	....do	....do	783.50
31	60	....do	....do	1,041.30
31	61	....do	....do	638.20
31	62	....do	....do	490.90
		Total		9,808.97

APRIL, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Apr. 8	1	Wm. A. Raborg	Traveling expenses	$70.69
8	2	Z. D. Gilman	Supplies	38.92
8	3	....do	....do	10.32

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

APRIL, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Apr.	8	4	The E. F. Brooks Co	Supplies	$3.40
	10	5	Department of the Interior	do	59.58
	10	6	do	do	2.42
	10	7	E. J. Pullman	do	22.20
	10	8	Herman Baumgarten	do	3.00
	10	9	Jno. C. Parker	do	1.50
	10	10	Wm. C. Day	Services, Mar. 16–31, 1896	70.00
	10	11	Altha T. Coons	Services, March, 1896	52.00
	10	12	Col., Hock.Val.& T.Rwy Co.	Transportation of assistant	9.95
	10	13	Robert L. Pollard	Report on nickel and cobalt	100.00
	10	14	F. H. Newell	Field expenses	35.00
	10	15	Shoemaker & Busch	Supplies	99.04
	10	16	Mackall Bros. & Flemer	do	33.72
	11	17	W. F. Hopson	Original drawings	250.00
	16	18	Z. D. Gilman	Supplies	2.60
	16	19	E. E. Jackson & Co	do	25.50
	16	20	D. R. Stansbury	Repairs	12.00
	16	21	Kennedy & Du Perow	Supplies	7.25
	22	22	E. W. Parker	Traveling expenses	101.98
	16	23	Henry Romeike	Press clippings	4.84
	15	24	Wm. A. Wansleben	Original drawings	50.00
	18	25	U. S. Express Co	Freight charges	12.14
	18	26	Meyer Bros. Drug Co	Supplies	3.15
	16	27	Smithsonian Institution	Transportation of exchanges	94.40
	21	28	Gustav Fock	Publications	279.46
	21	29	Citizens' National Bank	Bill of exchange	3.52
	21	30	Pennsylvania R. R. Co	Transportation of assistant	12.75
	21	31	Herman Baumgarten	Supplies	5.20
	22	32	David T. Day	Traveling expenses	93.45
	22	33	J. H. Chesley & Co	Laboratory supplies	.40
	24	34	Geo. F. Kunz	Services, March, 1896	100.00
	27	35	Chas. E. Munroe	Assay and analyses of ores	70.00
	30	36	do	Assay of coal and clay	99.00
	30	37	Baker & Co	Laboratory supplies	54.70
	30	38	M. W. Beveridge	do	2.14
	30	39	Wm. A. Wansleben	Preparation of charts	50.00
	30	40	C. C. Willard	Rent of office rooms	349.99
	30	41	do	do	100.00
	30	42	H. Gibb	Services, April, 1896	70.00
	30	43	L. P. Bush	do	65.00
	30	44	Pay roll of employees	do	2,464.10
	30	45	do	do	1,083.80
	30	46	do	do	511.50
	30	47	do	do	499.60
	30	48	do	do	758.20
	30	49	do	do	1,028.15
	30	50	do	do	580.80
	30	51	do	do	266.49
			Total		9,723.85

MAY, 1896.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
May	5	1	Robert Beall	Publications	$10.00
	6	2	Mackall Bros. & Flemer	Supplies	72.22
	6	3	Griffith Thornton	Services, April, 1896	2.50

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

MAY, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
May 8	4	Geo. F. Kunz	Services, April, 1896	$110.00
6	5	H. O. Hofman	Testing 4 fire clays	20.00
6	6	Henry Romeike	Press clippings	5.80
11	7	Geo. N. Rider	Publications	6.00
11	8	A. C. Peale	Services, Apr. 1-9, 1896	48.00
11	9	Altha T. Coons	Services, April, 1896	52.00
11	10	Charles E. Munroe	Analyses of coals and marls	132.50
13	11	E. A. Balloch	Rent of phonograph	40.00
13	12	Shoemaker & Busch	Supplies	51.73
14	13	A. C. Peale	Services, May 1-9, 1896	24.00
16	14	James T. White & Co	Publications	8.00
16	15	Wm. A. Wansleben	Publications of charts	50.00
16	16	Theodore Johnson	Traveling expenses	20.75
16	17	Southern Pacific Co	Transportation of assistant	24.20
16	18	J. B. Lippincott	Services, Mar. 3-31, 1896	34.00
16	19	B. M. Hall	Services, Apr. 28-30, 1896	18.00
16	20	S. Fortier	Services, Apr. 20-29, 1896	54.00
16	21	F. H. Newell	Field expenses	37.50
16	22	.....do	.....do	22.45
16	23	.....do	.....do	37.65
18	24	Z. D. Gilman	Supplies	47.97
18	25	Department of the Interior	.....do	112 27
18	26	.....do	.....do	17.76
18	27	.....do	.....do	.10
19	28	Mackall Bros. & Flemer	.....do	19.60
19	29	Geo. F. Muth & Co	.....do	41.35
19	30	J. A. Vogleson	Services, Apr. 3-30, 1896	168.00
19	31	F. H. Newell	Field expenses	36.21
21	32	Frank Burrs	Traveling expenses	9.85
22	33	Baker & Co	Laboratory supplies	239.75
23	34	R. R. Bowker	Publications	12.50
23	35	Wm. C. Day	Services, Apr. 1-15, 1896	60.00
23	36	W. G. Russell	Services, Mar. 19-Apr. 17, '96	42.00
23	37	E. C. Murphy	Services, Mar. 26-Apr-25, '96	35.00
23	38	Elwood Mead	Services, Apr. 14-30, 1896	88.00
23	39	F. H. Newell	Field expenses	43.90
23	40	.....do	.....do	48.00
23	41	.....do	.....do	20.00
23	42	.....do	.....do	34.00
23	43	.....do	.....do	23.40
26	44	L. H. Taylor	Services, Mar. 19-Apr. 27, '96	58.50
26	45	O. V. P. Stout	Services, Apr. 10-16, 1896	18.00
26	46	Houston & Texas Cent. R. R.	Transportation of assistant	5.00
26	47	Wm. C. Day	Traveling expenses	12.93
26	48	E. J. Pullman	Supplies	78.75
26	49	Wm. D. Castle	.....do	4.50
26	50	Wm. M. Fontaine	Services, July 1, '95-Apr. 30, 1896.	150.00
29	51	M. A. Tappan	Supplies	35.50
29	52	Wm. A. Wansleben	Preparation of drawings	50.00
29	53	C. C. Willard	Rent of office rooms	349.99
29	54	.....do	.....do	100.00
29	55	A. P. Davis	Services, May, 1896	170.40
29	56	Cyrus C. Babb	.....do	102.20
29	57	H. Gibb	.....do	70.00
29	58	L. P. Bush	.....do	65.00
29	59	Pay roll of employees	.....do	2,546.80
29	60	.....do	.....do	1,117.40
29	61	.....do	.....do	527.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

MAY, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
May	29	62	Pay roll of employces	Services	$518.80
	29	63	do	do	846.79
	29	64	do	do	983.70
	29	65	do	do	325.80
			Total		10,118.02

JUNE, 1896.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
June	3	1	Robert Beall	Publications	$29.75
	3	2	Frank Burns	Field expenses	56.18
	6	3	Henry Romeike	Press clippings	12.24
	6	4	Chas. E. Munroe	Analyses of coals	56.25
	6	5	Henry H. Brown	Illustration supplies	3.25
	6	6	Wykoff, Seamans & Benedict.	Repairs	6.75
	9	7	Department of the Interior	Supplies	95.32
	9	8	do	do	2.70
	10	9	Eimer & Amend	do	161.47
	10	10	Atch., Top. & S. F. Rwy. Co	Transportation of assistants	6.55
	10	11	The Wabash R. R. Co	do	5.45
	10	12	D. C. Humphreys	Cash paid for services and supplies.	41.00
	10	13	do	Services, Apr. 29-30, 1896	15.00
	10	14	F. Cogswell	Services, Apr. 27-May 27, '96	81.60
	12	15	W. G. Russell	Services, May 13-26, 1896	65.00
	12	16	A. M. Ryon	Services, May 11-18, 1896	45.50
	12	17	Lyman P. Kendall	Services, Apr. 25-May 26, '96	35.00
	12	18	L. H. Taylor	Services, May 18-29, 1896	24.00
	12	19	D. C. Humphreys	Services, May 15-29, 1896	25.00
	12	20	Samuel Fortier	Services, May 20-29, 1896	54.00
	12	21	O. V. P. Stout	Services, May 2-27, 1896	30.75
	12	22	E. C. Murphy	Services, May 25-29, 1896	24.00
	12	23	J. B. Lippincott	Services, May 20-29, 1896	30.37
	12	24	Elwood Mead	Services, May 6-29, 1896	150.15
	12	25	P. E. Harroun	Services, May 23-29, 1896	37.20
	12	26	F. H. Newell	Field expenses	16.80
	12	27	do	do	20.00
	12	28	Louis V. Pirsson	Analyses of rocks	240.00
	12	29	Chas. N. Jenks	Report on corundum	20.00
	15	30	Frank Burns	Traveling expenses	8.10
	15	31	do	Field expenses	26.35
	18	32	Wm. A. Wansleben	Preparation of maps	50.00
	18	33	J. C. McConnell	Original drawings	86.50
	18	34	W. Bruce Gray	do	111.00
	20	35	Mackall Bros. & Flemer	Supplies	19.69
	20	36	Ginn & Co	Publications	9.00
	20	37	Altha T. Coons	Services, May, 1896	52.00
	20	38	Mining Iron and Steel	1 copy Mining in Canada	4.00
	20	39	Chas. E. Munroe	Assay of ores	3.00
	20	40	Thomas Somerville & Sons	Laboratory supplies	1.00
	22	41	Z. D. Gilman	Supplies	117.04
	23	42	B. M. Hall	Services, May 8-22, 1896	15.00
	23	43	F. H. Newell	Cash paid for services and supplies.	93.78
	30	44	Shoemaker & Busch	Supplies	151.49
	30	45	Wm. A. Wansleben	Drawings	50.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1896—Continued.

JUNE, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
June 30	46	Wm. Bruce Gray	Drawings	$67.00
30	47	J. S. Hunter	.....do	82.00
30	48	Geo. F. Muth & Co	Supplies	32.56
30	49	Cyrus C. Babb	Field expenses	18.25
30	50	Alfeus Hyatt	Services, Dec. 1, 1895–Jan. 31, 1896.	100.00
30	51	H. Gibb	Services, June, 1896	70.00
30	52	L. P. Bush	.....do	65.00
30	53	C. C. Willard	Rent, June, 1896	349.99
30	54	.....do	.....do	100.00
30	55	Grace Caldwell	Services, May 1–4, 1896	7.50
30	56	The Acme Folding Boat Co	Field supplies	126.63
30	57	A. P. Davis	Traveling expenses	56.25
30	58	Heinrich Reis	.....do	179.35
30	59	.....do	.....do	4.85
30	60	J. B. Lippincott	Field expenses	85.65
30	61	A. P. Davis	.....do	82.25
30	62	F. H. Newell	Cash paid for services	48.00
30	63	Charles E. Munroe	Assay of ores	21.00
30	64	E. W. Meyers	Services, May 1–29, 1896	125.00
30	65	Pay roll of employees	Services, June, 1896	2,464.10
30	66	.....do	.....do	1,356.27
30	67	.....do	.....do	461.50
30	68	.....do	.....do	513.60
30	69	.....do	.....do	840.60
30	70	.....do	.....do	1,030.85
30	71	.....do	.....do	481.90
		Total		10,959.33

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896.

JULY, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
July 10	1	H. M. Wilson	Traveling expenses	$23.70
10	2	W. E. Doyle & Co	Field supplies	16.83
10	3	Spratlen & Anderson	Forage	49.18
16	4	Q. M. Department, U. S. A	Tents	158.30
16	5	Pennsylvania R. R. Co	Transportation of assistants	323.80
18	6	Louis. & Nash. R. R. Co	.....do	19.40
18	7	Wells-Fargo & Co	Freight	37.05
18	8	National Express Co	.....do	1.95
18	9	.....do	.....do	12.02
17	10	Henry Gannett	Traveling expenses	50.30
19	11	Q. M. Department, U. S. A	Geologic supplies	125.00
19	12	Henry J. Green	Geologic instruments	21.60
9	13	W. & L. E. Gurley	Supplies and repairs	60.10
27	14	Bailey Willis	Traveling expenses	52.80
24	15	Southern Railway Co	Transportation of assistant	16.55
31	16	H. M. Wilson	Traveling expenses	72.89
18	17	Baltimore & Ohio R. R. Co	Transportation of assistants	78.50
31	18	W. G. Thomas	Services, July 10–26, 1895	45.00
31	19	W. B. Williams	.....do	45.00
31	20	Pay roll of employees	Services, July, 1895	1,156.50
31	21	.....do	.....do	471.20
		Total		2,837.67

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

AUGUST, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Aug. 3	1	G. W. Saegmuller	Repairs to instruments	$30.00
6	2	Adams Express Co	Freight charges	162.35
6	3	Pay roll of employees	Services, July, 1895	90.00
8	4	Frank Burns	Field expenses	53.29
8	5	Wm. B. Clark	Services, July, 1895	125.00
7	6	Rio Grande & West. Rwy. Co.	Transportation of assistants	13.00
8	7	Colorado Midland R. R. Co	do	15.00
8	8	Southern Pacific Co	do	12.80
6	9	The Wabash R. R. Co	do	8.90
7	10	Bur. & Mo. Riv. R. R. in Nebr.	do	27.30
8	11	Chic., Bur., & Quincy R. R. Co.	do	25.25
7	12	Chic. & Northwestern R. R. Co	do	12.10
7	13	Baltimore & Ohio R. R. Co	do	475.00
6	14	J. M. Beaty & Co	Field supplies	65.57
7	15	Chesapeake & Ohio R. R. Co.	Transportation of assistants	115.30
10	16	H. M. Wilson	Traveling expenses	59.75
14	17	Q. M. Department, U. S. A	Tents	30.49
13	18	McDonald Grocery Co	Field supplies	27.22
13	19	J. M. Larson	Hire of tents, etc	49.50
14	20	do	Tents	45.00
13	21	Fred. Koch	Services, July 31, 1895	60.00
13	22	Charles R. Tyrell	Services, July 10–31, 1895	35.49
13	23	Geo. Otis Smith	Services, July 7–31, 1895	52.42
13	24	W. B. Williams	Services, July 29–31, 1895	5.80
13	25	J. S. Diller	Field expenses	181.76
14	26	W. E. Doyle & Co	Field supplies, etc	5.25
13	27	Spratlen & Anderson	do	23.21
13	28	do	do	62.07
13	29	W. H. Hyde	Repairs	16.75
15	30	L. W. Estes	Pasturage	7.41
13	31	R. C. McKinney	Field expenses	16.90
14	32	N. Y., C. & H. Riv. R. R. Co	Transportation of assistant	9.60
16	33	Geo. H. Eldridge	Traveling expenses	25.45
16	34	Pennsylvania R. R. Co	Transportation of assistant	78.50
12	35	Adams Express Co	Freight charges	60.50
17	36	Chas. D. Walcott	Traveling expenses	105.56
17	37	Southern Pacific Co	Transportation of assistant	5.90
17	38	A. H. Thompson	Field expenses	20.72
17	39	do	do	18 10
17	40	A. E. Murlin	do	5.00
20	41	M. G. Copeland & Co	Geologic supplies	2.40
20	42	Pacific Box Mfg. Co	Field material	9.00
20	43	Spratlen & Anderson	Supplies	75.17
20	44	Ordnance Dept. U. S. A	Field supplies	3.18
20	45	St. L. & San Fran. R. R. Co	Freight	2.25
21	46	James S. Topham	Geologic supplies	7.00
22	47	H. Hoffa	do	8.00
24	48	H. M. Wilson	Traveling expenses	36.66
26	49	Oregon Improvement Co	Supplies, forage, etc	22.58
26	50	McDonald Grocery Co	do	40.93
27	51	C. W. Goodlove	Services, June 1–16, 1895	39.56
24	52	U. S. Express Co	Freight charges	99.27
24	53	do	do	24 03
31	54	Frank Burns	Field expenses	41.56
31	55	do	Traveling expenses	27.20
31	56	Pay roll of employees	Services, August, 1895	1,173.30
31	57	do	do	171.20
		Total		4,322.50

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

SEPTEMBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 7	1	C. R. Van Hise	Services, August, 1895	$270.00
10	2	Michael Autier	Services, Aug. 17-31, 1895	24.19
10	3	Frederick Koch	Services, August, 1895	60.00
10	4	W. B. Williams	do	60.00
10	5	Geo. Otis Smith	do	65.00
9	6	H. M. Wilson	Traveling expenses	55.56
9	7	Henry Gannett	do	148.88
10	8	Bailey Willis	Field expenses	34.63
11	9	Wykoff, Seamans & Benedict	Supplies and repairs	3.50
11	10	Geo. F. Muth & Co	Topographers' supplies	1.80
11	11	do	Geologic supplies	.85
11	12	Geo. T. Ennis	Topographic supplies	1.20
12	13	L. H. Schneider's Son	Topographic and geologic supplies.	9.00
11	14	Southern Pacific Co	Transportation of assistants	18.70
11	15	Bur. & Mo. Riv. R. R. in Nebr.	do	50.00
11	16	M., St. P. & Sault Ste. M. Rwy.	do	9.90
11	17	Chic. & Northwestern Rwy. Co.	do	12.70
11	18	Baltimore & Ohio R. R. Co.	do	190.00
11	19	Horace Knight	Forage	15.00
14	20	Chas. D. Walcott	Traveling expenses	109.12
14	21	F. B. Weeks	do	62.77
16	22	Ft. W. & Denver City Rwy. Co	Transportation of assistants	13.55
16	23	U. P., Denver & Gulf Rwy. Co	do	10.25
16	24	Oreg. Rwy. & Nav gation Co	do	16.69
16	25	Southern Railway Co	do	16.55
16	26	Northern Pacific Co	do	40.63
20	27	Bailey Willis	Field expenses	41.30
20	28	J. S. Diller	do	212.96
20	29	A. H. Thompson	do	14.17
20	30	do	do	30.16
20	31	Townsend & Lance	Field supplies	15.44
20	32	Department of the Interior.	Geologic supplies	23.88
25	33	Norfolk & Western Rwy. Co	Transportation of assistant.	9.80
25	34	Stevens & Moore	Field supplies	19.15
30	35	W. T. Griswold	Field expenses	135.00
27	36	Bailey Willis	do	28.70
27	37	Cin., N. O. & Tex. Pac. R. R. Co.	Transportation of assistant.	18.70
30	38	Atch., Top. & S. F. Rwy. Co.	do	20.65
30	39	H. M. Wilson	Traveling expenses	47.20
30	40	Pay roll of employees	Services, September, 1895	1,138.40
30	41	do	do	457.60
		Total		3,513.58

OCTOBER, 1895.

Oct. 2	1	Frederick Koch	Services, September, 1895	$60.00
2	2	Michael Autier	do	55.00
2	3	W. B. Williams	do	60.00
2	4	Geo. Otis Smith	do	65.00
2	5	Warren Upham	Services, July 1–Sept. 18, '95	170.00
2	6	Chic., Mil. & St. P. Rwy. Co.	Transportation of assistants	9.28
2	7	Oreg. S. L. & U. N. Rwy. Co.	do	14.40
4	8	Baltimore & Ohio R. R. Co.	do	26.75

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

OCTOBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Oct. 4	9	The Wabash R. R. Co	Transportation of assistants	$11.50
5	10	Oreg. S. L. & U. N. Rwy. Co	do	15.82
4	11	U. S. Express Co	Freight charges	68.61
4	12	Adams Express Co	do	46.75
10	13	United Typewriter and Supplies Co.	Repairs	2.00
10	14	Western Pacific R. R. Co	Transportation of assistants	77.55
10	15	Southern Pacific Co	do	12.00
10	16	Southern Railway Co	do	50.28
10	17	Chas. D. Walcott	Traveling expenses	270.02
12	18	J. T. McDevitt	Subsistence supplies, etc	39.05
12	19	Monte Cristo Mercantile Co	do	8.18
12	20	A. H. Thompson	Field expenses	60.73
12	21	Henry Gannett	Traveling expenses	127.25
11	22	B. E. Green	Forage	23.00
14	23	Spratlen & Anderson	Subsistence supplies, etc	31.89
10	24	Robert Floerman	Storage	3.00
15	25	F. B. Weeks	Traveling expenses	84.85
14	26	Oreg. Rwy. & Navigation Co	Transportation of assistants	32.20
14	27	Chesapeake & Ohio Rwy. Co	do	28.80
25	28	Department of the Interior	Geologic supplies	7.63
25	29	William Kerr	do	12.00
25	30	Franklin & Co	do	1.70
25	31	H. M. Wilson	Traveling expenses	87.20
26	32	Michael Antier	Services, Oct. 1-12, 1895	19.35
26	33	Frederick Koch	do	23.23
28	34	Bailey Willis	Traveling expenses	5.00
28	35	do	do	12.17
28	36	do	do	125.57
28	37	do	Field expenses	61.50
26	38	Geo. O. Smith	Traveling expenses	18.05
26	39	do	do	3.00
29	40	Int. & Great Nor. Rwy. Co	Transportation of assistants	38.45
29	41	Pennsylvania R. R. Co	do	12.20
20	42	Northern Pacific R. R. Co	do	62.00
29	43	The Wabash R. R. Co	do	22.75
31	44	Bailey Willis	Field expenses	70.20
31	45	do	do	62.91
31	46	Joseph P. Iddings	Services, July, 1895	182.00
31	47	Pay roll of employees	Services, October, 1895	1,173.30
31	48	do	do	471.20
		Total		3,9[illegible]4.41

NOVEMBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Nov. 9	1	Department of the Interior	Geologic supplies	$18.86
11	2	W. & L. E. Gurley	do	44.00
11	3	do	Topographic supplies	4.14
12	4	Fayette R. Plumb	Geologic supplies	41.40
12	5	Denver & Rio Gr. R. R. Co	Freight	78.00
12	6	Atch., T., & S. F. Rwy. Co	do	1.60
12	7	Galv., Har. & S. An. Rwy. Co	do	1.42
12	8	Bur. & Mo. Riv. R. R. in Nebr	Transportation of assistants	34.63
12	9	Chic., Bur. & Quincy R. R. Co	do	12.75
13	10	Gulf, Colo. & S. Fe R. R. Co	do	34.95
13	11	U. P., Denver & Gulf Rwy. Co	do	16.60

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

NOVEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Nov. 13	12	Delaware & Hudson Canal Co	Transportation of assistants	$11.30
13	13	Northern Pacific R. R. Co	Transportation of property	8.37
13	14	U. P., Denver & Gulf Rwy. Co	do	5.83
13	15	Missouri Pacific Rwy. Co	do	.53
13	16	Geo. W. Hobbs	do	.12
13	17	do	do	.89
15	18	Northern Pacific R. R. Co	Transportation of assistants	112.70
15	19	Southern Pacific Co	do	37.40
15	20	Baltimore & Ohio R. R. Co	do	129.60
15	21	W. B. Williams	Services, Oct. 1–12, 1895	23.22
19	22	J. S. Diller	Field expenses	1.25
19	23	do	do	1.05
19	24	do	do	167.38
19	25	do	do	89.80
19	26	do	Traveling expenses	77.80
20	27	Fred Reh	Geologic supplies	12.50
19	28	Samuel Storrow	1 mule, use of team, etc	129.10
20	29	Frederick Koch	Field expenses	58.50
20	30	do	Traveling expenses	18.55
20	31	A. H. Thompson	do	65.25
19	32	L. P. Siebold	Cleaning case of microscope, etc.	2.50
20	33	Edward Kübel	Repairs of instruments	52.00
21	34	Great Northern Rwy. Co	Transportation of assistants	110.20
21	35	Pennsylvania R. R. Co	do	58.50
21	36	Den., Lead. & Gun. Rwy. Co	do	8.00
20	37	Frederick Springmann	Transportation of property	3.60
22	38	W. H. Weed	Traveling expenses	58.55
16	39	C. H. Underwood	Services, Nov. 1–17, 1895	22.66
23	40	W. A. Pate	Geologic supplies	17.10
23	41	Z. D. Gilman	do	3.25
26	42	H. S. Wallace	Traveling expenses	18.50
26	43	E. E. Jackson & Co	Supplies	73.00
27	44	Jno. C. Parker	do	22.50
30	45	E. J. Pullman	do	28.72
30	46	Joe Minton	Making map	16.00
30	47	Pay roll of employees	Services, November, 1895	2,068.44
30	48	do	do	554.40
30	49	do	do	937.80
30	50	do	do	457.60
		Total		5,752.81

DECEMBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Dec. 4	1	Chas. D. Walcott	Traveling expenses	$66.35
5	2	A. H. Thompson	Field expenses	53.69
5	3	do	do	51.04
7	4	Stephenson's Express	Freight and hauling	29.66
7	5	G. K. Gilbert	Traveling expenses	21.77
7	6	do	do	56.70
9	7	Northern Pacific Co	Transportation of property	2.60
9	8	Missouri Pacific Rwy	do	4.21
9	9	Rio Grande Western Rwy. Co	Transportation of assistants	11.65
9	10	Chic., Bur. & Quincy R. R. Co	do	44.75
9	11	Denver & Rio G. R. R. Co	do	24.95

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

DECEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Dec. 9	12	Oreg., S. L. & U. N. Rwy. Co.	Transportation of assistants	$64.20
9	13	Chesapeake & Ohio R. R. Co.	......do	19.70
9	14	Chic.& Northwestern R.R.Co	......do	19.93
9	15	C., M. & St. P. Rwy. Co.	......do	25.20
9	16	Southern Pacific Co	......do	6.55
9	17	The Wabash R. R. Co	......do	22.50
9	18	Bur. & Mo. Riv. R.R. in Nebr.	......do	66.50
9	19	Texas Pacific Rwy. Co	......do	6.60
9	20	Queen & Co (incorporated)	Instruments	123.80
9	21	Robert Fhormann	Storage	9.00
9	22	Pennsylvania R. R. Co	Transportation of assistant.	17.50
10	23	Geo. Otis Smith	Services Nov., 1895	65.00
9	24	Chic , St. P., M. & O. Rwy.Co	Transportation of assistants	23.70
10	25	......do	......do	7.90
10	26	Kan.City, St. Joe & C.B.Rwy	......do	17.05
10	27	Southern Railway Co	......do	38.80
12	28	Baltimore & Ohio R. R. Co.	Transportation of property.	.84
12	29	......do	......do	16.12
12	30	St. Joe & Grand Is. R. R. Co.	Transportation of assistants	2.97
12	31	Gal., Har. & S. An. Rwy. Co.	Transportation of property.	9.36
13	32	Southern Pacific Co	Transportation of assistants	58.05
13	33	Hous. & Tex. Cen. R. R. Co.	......do	5.35
13	34	Chic., Mil. & St. Paul Rwy.Co	......do	31.50
13	35	Bur. & Mo. Riv. R. R. in Nebr	......do	36.20
13	36	Department of the Interior	Geologic supplies	2.21
13	37	......do	Topographer's supplies	12.48
13	38	......do	......do	24.09
14	39	Great Northern Rwy. Co	Transportation of assistant.	77.50
14	40	Oreg. Rwy. & Navigation Co.	......do	25.19
19	41	Edward Kübel	Repairs	35.75
17	42	The Wabash R. R. Co	Transportation of assistants	11.50
17	43	G. N. Saegmuller	Repairs	42.50
17	44	......do	......do	2.75
19	45	Bousch & Lamb Optical Co.	Supplies	8.00
19	46	......do	......do	24.00
19	47	Joseph P. Iddings	Services Sept. 1-25, 1895	140.00
19	48	Oreg. S. L. & U. N. Rwy. Co.	Transportation of assistants	20.25
19	49	Oreg. Rwy. & Navigation Co.	......do	62.41
23	50	John Macraedy & Co	Field supplies	20.80
23	51	The E. F. Brooks Co	Geologic supplies	2.50
23	52	Bailey Willis	Field expenses	6.00
23	53	Atch., Top. & S. F. Rwy. Co.	Transportation of assistant.	70.00
31	54	W. Zinsser	Geographic supplies	5.50
31	55	George W. Driver	Care of and forage of animals	12.90
31	56	......do	......do	48.00
31	57	Alice M Onthank	Services, December, 1895	50.00
31	58	Pay roll of employees	......do	2,681.10
31	59	......do	......do	1,229.80
31	60	......do	......do	1,954.10
		Total		7,630.52

JANUARY, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Jan. 6	1	John C. Parker	Geologic supplies	$21.25
8	2	Geo. W. Knox Express Co	Freight charges and hauling	105.49
8	3	U. S. Express Co	......do	416.90

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JANUARY, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Jan.	8	4	Adams Express Co	Freight charges and hauling	$101.85
	8	5	Lester F. Ward	Traveling expenses	99.95
	8	6	.....do	.....do	142.55
	8	7	Henry J. Green	Geologic instruments	65.70
	11	8	Northern Pacific R. R. Co	Transportation of property	90.51
	11	9	Atch., Top. & S. F. Rwy. Co.	Transportation of assistants	68.64
	11	10	Mo., Kan. & Texas Rwy. Co.	.....do	38.00
	11	11	Rio Grande West. Rwy. Co	.....do	15.00
	11	12	Colorado Midland R. R	.....do	12.00
	11	13	Chic., Mil. & St. P. Rwy. Co	.....do	12.50
	11	14	Chic. & Northwestern R. R	.....do	12.50
	11	15	U. P., Denver & Gulf Rwy	.....do	12.30
	11	16	T. H. & Ind. Rwy. Co	.....do	21.00
	11	17	Southern Railway Co	.....do	21.60
	15	18	Northern Pacific R. R. Co	Transportation of property	66.52
	15	19	Oreg. Rwy. & Navigation Co.	.....do	21.20
	15	20	C. Schneider	Supplies	1.05
	16	21	E. F. Brooks Co	.....do	3.00
	16	22	Denver & Rio G. R. R. Co	Transportation of assistants	20.90
	16	23	Baltimore & Ohio R. R. Co	.....do	14.40
	16	24	Denver & Rio G. R. R. Co	Transportation of property	9.61
	16	25	Pacific Express Co	.....do	24.58
	16	26	Department of the Interior	Supplies	39.34
	16	27	.....do	.....do	39.34
	16	28	.....do	.....do	39.34
	16	29	.....do	.....do	28.57
	16	30	.....do	.....do	31.88
	18	31	J. E. Spurr	Field expenses	11.85
	17	32	Int. & Great Nor. Rwy. Co	Freight	.84
	20	33	Fred Reh	Geologic supplies	13.50
	20	34	Herman Baumgarten	Supplies and repairs	3.85
	24	35	Voight & Hochgesang	Geologic supplies	93.41
	24	36	R. Fuess	.....do	386.36
	24	37	Citizens' National Bank	Bills of exchange	9.08
	23	38	J. H. Chesley & Co	Geographic repairs	3.65
	23	39	Geo. W. Driver	Care and forage of public animals.	48.00
	28	40	Southern Pacific Co	Transportation of assistants	102.50
	28	41	Bur. & Mo. Riv. R. R. in Nebr.	.....do	44.75
	31	42	M. G. Copeland & Co	Geologic supplies	7.00
	31	43	.....do	.....do	5.00
	31	44	Conrad Becker	.....do	16.75
	31	45	Frederick J. H. Merrill	Services, Sept. 4, 1895–Jan. 1, 1896.	200.00
	31	46	Pay roll of employees	Services, January, 1896	1,626.80
	31	47	.....do	.....do	1,413.80
	31	48	.....do	.....do	3,354.22
	31	49	.....do	.....do	150.00
			Total		9,092.28

FEBRUARY, 1896.

Feb.	7	1	Northern Pacific R. R. Co	Transportation of assistants	$46.50
	7	2	.....do	.....do	11.00
	7	3	Pennsylvania R. R. Co	.....do	35.00
	12	4	Denver & Rio G. R. R. Co	Transportation of property	3.15

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

FEBRUARY, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Feb.	12	5	Rio Grande Southern Rwy	Transportation of property	$5.95
	12	6	Jno. C. Branner	Services, Jan. 1–Feb. 5, 1896	300.00
	14	7	A. C. Peale	Services, Feb. 7–13, 1896	30.00
	14	8	Franklin & Co	Geologic supplies	20.00
	14	9	Geo. F. Muth & Co	do	23.00
	14	10	Fred Reh	do	7.75
	14	11	John C. Parker	do	2.40
	14	12	J. W. Drew & Co	Geologic supplies and repairs.	17.65
	14	13	Samuel Storrow	Storage	9.00
	14	14	Fred A. Schmidt	Supplies	9.87
	14	15	Baltimore & Ohio R. R. Co	Freight	.72
	14	16	do	Transportation of assistant	17.50
	15	17	Department of the Interior	Supplies	9.60
	15	18	do	do	9.60
	15	19	do	do	9.60
	15	20	do	do	20.31
	15	21	do	do	14.27
	18	22	Bausch & Lamb Optical Co	do	16.00
	18	23	Wm. D. Castle	do	.50
	18	24	M. W. Beveridge	do	1.20
	18	25	J. Baumgarten & Sons	do	5.15
	18	26	J. E. Hurley	Repairs	9.50
	18	27	Rio Grande West. Rwy. Co	Transportation of assistant	19.60
	18	28	Northern Pacific R. R. Co	Transportation of property	1.06
	18	29	Louis. & Nash. R. R. Co	Transportation of assistant	15.20
	20	30	Baltimore & Ohio R. R. Co	Transportation of property	12.16
	20	31	Thos. W. Smith	Geologic supplies	50.00
	21	32	Herman Baumgarten	Geologic repairs	.75
	21	33	do	do	2.00
	24	34	Fred Reh	Geologic supplies	14.00
	24	35	Jno. C. Parker	do	.25
	24	36	E. E. Jackson & Co	Supplies	57.12
	29	37	Thos. W. Smith	do	242.40
	29	38	Edward Kiebel	Repairs	8.35
	29	39	E. C. Driver	Forage	18.00
	29	40	Jos. Perrin Smith	Services, Dec. 1, 1895–Feb. 15, 1896.	150.00
	29	41	Pay roll of employees	Services, February, 1896	1,601.00
	29	42	do	do	1,322.40
	29	43	do	do	3,287.00
	29	44	do	do	169.78
			Total		7,636.29

MARCH, 1896.

Mar.	7	1	John Hunton	Care and forage of public animals.	$22.50
	7	2	L. H. Schneider's Son	Supplies	9.60
	7	3	Wm. Kerr	do	12.00
	7	4	Henry H. Brown	do	12.29
	7	5	Chic. & Northwestern R. R	Transportation of assistants	12.50
	7	6	Pennsylvania R. R. Co	do	17.50
	7	7	T. H. & Ind. Rwy Co	do	20.25
	7	8	Oreg. Rwy. & Navigation Co.	Transportation of property	1.80

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

MARCH, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Mar. 7	9	Pennsylvania R. R. Co	Transportation of property	$2.62
11	10	Oreg. Rwy. & Navigation Co	do	2.69
11	11	Missouri Pacific Rwy. Co	do	.27
11	12	Baltimore & Ohio R. R. Co	do	4.72
7	13	Chic. Great West. Rwy. Co	do	1.89
7	14	do	do	1.19
11	15	U. P., Denver & Gulf Rwy	Transportation of assistant	13.18
12	16	Department of the Interior	Supplies	1.26
12	17	do	do	4.23
14	18	J. V. Lewis	Microphotographs of rock sections.	20.00
21	19	Jno. C. Parker	Supplies	63.00
23	20	W. A. Pate	do	5.70
21	21	U. S. Express Co	Freight charges	73.63
21	22	Adams Express Co	do	233.90
21	23	Geo. W. Knox Express Co	Freight charges and hauling	69.84
31	24	Stephenson's Express	do	55.97
31	25	W. & L. E. Gurly	Supplies	70.00
31	26	U. S. Electric Lighting Co	do	4.80
31	27	Fayette R. Plumb	do	21.60
31	28	Frederick Koch	Traveling expenses	22.20
31	29	Mrs. E. C. Driver	Forage of public animals	48.00
31	30	Pay roll of employees	Services, March, 1896	1,827.69
31	31	do	do	1,200.90
31	32	do	do	3,539.71
31	33	do	do	384,56
		Total		7,782,02

APRIL, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Apr. 7	1	A. C. Peale	Services, March, 1896	$21.00
10	2	Geo. W. Knox Express Co	Freight charges and hauling	15.35
10	3	Wm. Kerr	Supplies	12.00
10	4	E. J. Pullman	do	14.69
10	5	Department of the Interior	do	5.00
10	6	do	do	7.88
8	7	The E. F. Brooks Co	do	2.45
10	8	Herman Baumgarten	do	.75
10	9	Colorado Midland R. R	Freight charges	1.40
10	10	Oreg. Rwy & Navigation Co	do	7.50
16	11	H. Hoffa	Geologic supplies	1.75
16	12	E. E. Jackson & Co	do	6.50
16	13	Ernest Kübel	Topographic supplies	5.00
16	14	Chesapeake & Ohio Rwy. Co	Transportation of assistants	54.05
18	15	U. S. Express Co	Transportation of property	7.75
18	16	Baltimore & Ohio R. R. Co	do	9.01
18	17	Atch., Top. & S. F. Rwy. Co	do	6.35
18	18	U.P., Denver & Gulf Rwy. Co	do	3.34
21	19	Geo. H. Stone	Cash paid for 1 atlas	10.00
21	20	Q. M. Department, U. S. A	Tentage	16.18
22	21	Southern Railway Co	Transportation of assistant	25.25
24	22	Geo. W. Knox Express Co	Freight charges and hauling	3.79
24	23	Southern Pacific Co	do	5.62
24	24	Great Northern Rwy. Co	do	4.05
24	25	E. C. Driver	Care and forage of public animals.	48.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

APRIL, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Apr. 25	26	Jas. S. Topham	Geologic repairs	$0.75
25	27	.....do	Geologic supplies	4.00
25	28	Franklin & Co	.....do	13.50
30	29	R. A. Daniel	.....do	12.00
30	30	Andrew B. Graham	Photolithographic transfers	7.50
30	31	Pay roll of employees	Services, April, 1896	1,870.90
30	32	.....do	.....do	1,162.50
30	33	.....do	.....do	3,560.91
30	34	.....do	.....do	196.76
		Total		7,122.98

MAY, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
May 6	1	John C. Branner	Services, March, 1896	$40.00
6	2	Mackall Bros. & Flemer	Geologic supplies	.48
6	3	Jas. S. Topham	Topographic supplies	11.20
8	4	Baltimore & Ohio R. R. Co	Freight	4.29
8	5	L. P. Siebold	Freight and custom charges	14.19
11	6	H. M. Wilson	Traveling expenses	34.27
13	7	Joseph P. Iddings	Services, Mar. 6-31, 1896	140.00
16	8	Geo. Otis Smith	Services, March, 1896	65.00
16	9	Thos. W. Smith	Supplies	103.60
18	10	Z. D. Gilman	.....do	.28
18	11	Department of the Interior	.....do	20.00
18	12	.....do	.....do	20.47
18	13	.....do	.....do	20.47
18	14	.....do	.....do	20.46
18	15	.....do	.....do	1.80
19	16	Geo. F. Muth & Co	.....do	7.10
21	17	Mrs. E. C. Driver	Forage of public animals	48.00
22	18	G. N. Saegmueller	Repairs of instruments	5.00
22	19	Geo. P. Merrill	Traveling expenses	10.30
26	20	E. J. Pullman	Supplies	5.50
26	21	Wm. D. Castle	.....do	5.00
29	22	Fayette R. Plumb	.....do	15.00
29	23	W. G. Copeland & Co	.....do	18.00
29	24	Pay roll of employees	Services, May, 1896	1,933.20
29	25	.....do	.....do	1,383.00
29	26	.....do	.....do	3,566.81
29	27	.....do	.....do	273.20
		Total		7,766.62

JUNE, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
June 6	1	G. K. Gilbert	Traveling expenses	$37.96
6	2	.....do	Field expenses	28.65
6	3	Henry H. Brown	Supplies	5.18
9	4	Department of the Interior	.....do	52.28
9	5	.....do	.....do	52.28
9	6	.....do	.....do	51.64
9	7	.....do	.....do	9.63
10	8	Jos. Perrin Smith	Services, Feb. 16-May 31, 1896.	150.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

June, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
June 10	9	Bausch & Lamb Optical Co.	Supplies	$16.10
12	10	Geo. B. Frazer	Collecting and shipping specimens.	4.60
12	11	Jos. S. Stone	Pasturage	48.00
6	12	Wykoff, Seamans & Benedict	Repairs	6.00
12	13	C. W. Parker & Co	Supplies	13.10
20	14	Baltimore & Ohio R. R. Co	Freight	3.64
20	15	Oreg. Rwy. & Navigation Co.	.....do	10.08
20	16	The State General Land Office of Texas.	Maps	5.00
20	17	G. N. Saegmuller	Geologic instruments	92.25
20	18	M. A. Tappan	Geologic supplies	15.50
20	19	Henry H. Brown	.....do	22.00
20	20	Mackall Bros. & Flemer	Topographic supplies	2.48
20	21	Edward Kübel	Topographic repairs	4.00
22	22	Z. D. Gilman	.....do	5.60
23	23	H. M. Wilson	Traveling expenses	12.44
23	24	Pennsylvania R. R. Co	Transportation of assistants	9.60
23	25	Joseph P. Iddings	Services, May 1-14, 1896	84.00
23	26	H. G. Heisler	Services, June 1-12, 1896	24.00
23	27	Yuem Wo	Services, June 1-9, 1896	13.50
23	28	Chic., Bur. & Quincy R. R. Co.	Freight	.67
24	29	C. W. Parker & Co	Field supplies	2.30
23	30	W. T. Lane	2 mules	150.00
25	31	A. P. Davis	Field expenses	45.30
25	32	Herman Barghausen	Geologic supplies	16.75
25	33	Wm. H. Hobbs	Services, June 1-9, 1896	102.00
25	34	Frederick Springman	Hauling	7.80
25	35	Chic., Bur. & Quincy R. R. Co.	Freight	2.27
25	36	.....do	.....do	2.00
30	37	Geo. F. Muth & Co	Topographic supplies	3.50
30	38	Cyrus C. Babb	Field expenses	36.25
30	39	Franklin & Co	Field glasses	84.00
30	40	Chic. & Northwestern R. R. Co.	Freight	.43
30	41	S. S. Gannett	Services, June, 1896	164.80
30	42	Pay roll of employees	.....do	1,475.20
30	43	.....do	.....do	392.87
30	44	.....do	.....do	1,827.33
30	45	.....do	.....do	166.90
30	46	.....do	.....do	132.40
		Total		5,392.28

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896.

1895.				
Apr. 11	1	Henry J. Green	Instruments	$47.81
12	2	Q. M. Department, U. S. A	Field material	974.58
15	3	G. N. Saegmuller	Instruments	500.00
15	4	Edward Kübel	Services, Mar. 15-31, 1895	95.96
17	5	Z. D. Gilman	Supplies	.10
22	6	Mackall Bros. & Flemer	.....do	6.75
24	7	G. N. Saegmuller	Instruments	600.00
29	8	L. H. Schneider's Son	Supplies	2.25
30	9	Edward Kübel	Services, April, 1895	175.00
30	10	S. S. Gannett	.....do	164.80

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
1895.					
Apr.	30	11	Geo. T. Hawkins	Services, April, 1895	$131.90
	30	12	Wm. J. Peters	do	131.90
	30	13	Robert A. Farmer	do	98.90
May	10	1	James A. Topham	Supplies	4.50
	10	2	W. & L. E. Gurley	do	9.00
	21	3	do	Instruments and repairs	1,140.50
	25	4	Pennsylvania R. R. Co	Transportation of assistants	57.00
	31	5	Q. M. Department, U. S. A	Tents, etc	552.90
	31	6	R. B. Cameron	Services, Apr. 16–May 31, '95	46.00
	31	7	Edward Kübel	Services, May, 1895	175.00
June	3	1	Department of the Interior	Supplies	44.40
	10	2	Herman Baumgarten	do	1.75
	11	3	Geo. F. Muth & Co	do	90.00
	11	4	W. & L. E. Gurley	Repairs of instruments	126.00
	11	5	Chesapeake & Ohio Rwy. Co	Transportation of assistants	105.15
	11	6	Mo., Kan. & Tex. Rwy. Co	do	10.10
	13	7	do	do	7.25
	15	8	Geo. F. Muth & Co	Sandpaper	.12
	17	9	Geo. N. Saegmuller	Repairs to instruments	345.60
	19	10	L. H. Schneider's Son	Supplies	2.03
	20	11	Department of the Interior	do	305.00
	21	12	Pennsylvania R. R. Co	Transportation of assistants	65.00
	28	13	Queen & Co. (incorporated)	Instruments	360.00
	30	14	Fred. A. Schmidt	Supplies	9.95
	30	15	Edward Kübel	Services, June, 1895	175.00
July	9	1	W. & L. E. Gurley	Instruments	1,015.80
	11	2	U. S. Express Co	Freight charges	111.50
	16	3	Q. M. Department, U. S. A	Tents	397.04
	19	4	W. & L. E. Gurley	Material	2.60
	18	5	Edward Kübel	Services, July 1–15, 1895	81.67
	25	6	T. H. & Ind. R. R. Co	Tronsportation of assistant	20.25
	31	7	Pay roll of employees	Services, July, 1895	102.58
Aug.	3	1	G. N. Saegmuller	Repairs to instruments	7.25
	6	2	Adams Express Co	Freight charges	19.95
	8	3	Mo., Kan. & Texas Rwy. Co	Transportation of assistant	14.25
	16	4	Pennsylvania R. R. Co	do	36.50
	20	5	M. G. Copeland & Co	Supplies	36.00
	21	6	James S. Topham	do	2.50
	24	7	U. S. Express Co	Freight charges	4.90
	26	8	National Express Co	do	64.93
	26	9	Mo., Kan. & Texas Rwy. Co	do	149.13
	31	10	Pay roll of employees	Services August, 1895	258.26
Sept.	12	1	L. H. Schneider's Son	1 gross screws	.43
	20	2	Department of the Interior	Supplies	5.76
	25	3	Pennsylvania R. R. Co	Transportation of assistants	36.50
	27	4	W. & L. E. Gurley	Repairs to instruments	12.25
	30	5	Pay roll of employees	Services, September, 1895	277.80
Oct.	25	1	Herman Baumgarten	Supplies	3.25
	25	2	Department of the Interior	do	20.00
	31	3	Pay roll of employees	Services, October, 1895	221.10
Nov.	9	1	Department of the Interior	Supplies	75.00
	9	2	do	do	61.75
	11	3	W. & L. E. Gurley	Instruments, etc	198.90
	11	4	do	do	586.50
	11	5	do	Supplies	16.00
	15	6	Missouri Pacific Rwy	Freight	62.00
	18	7	Maggie M. Loeffler	Services, October, 1895	60.00
	20	8	Edward Kübel	Repairs to instruments	13.00

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
1895.					
Nov.	30	9	Pay roll of employees	Services, November, 1895	$243.80
Dec.	9	1	W. & L. E. Gurley	24 timber scribes	24.00
	9	2	Mo., Kan. & Texas Rwy Co	Transportation of assistants	23.90
	9	3	Maggie M. Loeffler	Services, Nov. 1-17, 1895	34.00
	13	4	Department of the Interior	Supplies	6.24
	17	5	G. N. Saegmuller	Repairs	30.25
	19	6	Edward Hübel	do	13.75
	19	7	Pennsylvania R. R. Co	Transportation of assistants	73.00
	31	8	Pay roll of employees	Services, December, 1895	527.22
1896.					
Jan.	8	1	Adams Express Co	Freight charges	5.25
	8	2	U. S. Express Co	do	28.60
	8	3	W. & L. E. Gurley	Repairs	19.20
	16	4	do	Instruments	975.47
	16	5	Department of the Interior	Supplies	39.33
	23	6	Q. M. Department, U. S. A	Tents	202.17
	25	7	R. M. Towson	Services, Jan. 1-15, 1896	57.69
	31	8	M. G. Copeland & Co	Supplies	4.80
	31	9	Pay roll of employees	Services, January, 1896	469.70
Feb.	5	1	Appropriation for Public Printing and Binding, 1896; allotment for Department of the Interior.	Note books	75.00
	14	2	G. N. Saegmuller & Co	Repairs of instruments	22.00
	14	3	do	Putting plates on compasses	60.00
	14	4	Contingent expenses, Department of the Interior.	1 typewriter	49.49
	15	5	Department of the Interior	Supplies	76.80
	17	6	Kate B. Webb	Services, Feb. 1-5, 1896	10.34
	18	7	Wykoff, Seamans & Benedict	Supplies and repairs	6.50
	18	8	Fred. J. Lung	do	65.00
	18	9	M. J. Copeland & Co	do	4.80
	18	10	Department of the Interior	3 typewriters	148.47
	29	11	W. & L. E. Gurley	Supplies	9.45
	29	12	Pay roll of employees	Services, February, 1896	447.75
Mar.	7	1	W. & L. E. Gurley	12 chains and expressage	104.65
	7	2	do	Repairs and expressage	15.50
	12	3	Department of the Interior	Supplies	4.32
	21	4	U. S. Express Co	Freight charges	17.06
	21	5	Adams Express Co	do	18.20
	31	6	W. & L. E. Gurley	Tavers and table blanks	6.00
	31	7	Pay roll of employees	Services, March, 1896	647.50
Apr.	10	1	Department of the Interior	Supplies	5.23
	10	2	National Express Co	Freight charges	36.37
	16	3	Fred. J. Lung	Map cases	65.00
	16	4	Chesapeake & Ohio Rwy. Co	Transportation of assistants	35.00
	18	5	Public printing and binding, 1896.	Supplies	62.50
	18	6	U. S. Express Co	Freight charges	8.07
	30	7	Pay roll of employees	Services, April, 1896	638.70
May	13	1	W. & L. E. Gurley	Repairs to instruments	180.00
	16	2	Pennsylvania R. R. Co	Transportation of assistants	57.50
	18	3	Department of the Interior	Supplies	67.62
	19	4	Public printing and binding, Department of Interior, '96.	do	88.50
	19	5	Geo. F. Muth & Co	Paint brushes	1.50
	22	6	G. N. Saegmuller	Repairs of instruments	78.00
	23	7	T. H. & Ind. R. R. Co	Transportation of assistant.	20.25
	26	8	E. J. Pullman	Supplies	7.20

Abstract of disbursements made by John D. McChesney, chief disbursing clerk, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
1896.				
May 29	9	Pay roll of employees	Services, May, 1896	$814.05
June 6	1	Wykoff, Seamans & Benedict	Repairs	12.00
9	2	Department of the Interior	Supplies	77.71
10	3	Mo., Kan. & Texas Rwy. Co	Transportation of assistant	15.50
18	4	Q. M. Department, U. S. A	Tentage	336.95
30	5	Franklin & Co	Field glasses	14.00
30	6	Pay roll of employees	Services. June, 1896	823.85
		Total		18,553.25

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, from April 1, 1895, to June 30, 1896.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

APRIL, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Apr. 1	1	C. H. Fitch	Services	$111.11
2	2	Sparks Bros	Field material	2,685.00
2	3	J. S. Welch	.....do	909.00
2	4	F. Weber & Sons	.....do	518.15
2	5	Emory, Bird, Thayer & Co	.....do	85.61
11	6	William J. Peters	Traveling expenses	16.50
11	7	Geo. T. Hawkins	.....do	78.00
11	8	.....do	Feld expenses	20.70
11	9	C. H. Fitch	Traveling expenses	45.25
11	10	Pay roll	Services	24.00
11	11	Geo. T. Hawkins	Field expenses	131.79
12	12	Frank Smith	Field supplies	307.60
12	13	.....do	.....do	88.70
13	14	S. S. Gannett	Traveling expenses	49.99
17	15	.....do	Field expenses	29.60
17	16	Chas. F. Urquhart	Traveling expenses	32.65
17	17	.....do	Field expenses	67.00
18	18	Frank Smith	Field supplies	288.48
19	19	P. H. Wilhelm	Board	32.87
19	20	R. O. Gordon	Traveling expenses	52.30
19	21	H. L. Baldwin, jr	.....do	52.80
30	22	C. H. Fitch	Services	206.00
30	23	Pay roll	.....do	323.00
30	24	.....do	.....do	289.07
		Total		6,445.17

MAY, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
May 2	1	Sparks Bros	Mules and horses	$4,619.50
2	2	F. Weber & Sons	Field material	737.89
4	3	Emery, Bird, Thayer & Co	.....do	133.19
4	4	J. S. Welch	.....do	1,481.20

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

MAY, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
May 4	5	Shipley Bros	Field material	$92.00
6	6	S. S. Gannett	Field expenses	76.98
6	7	W. T. Culbertson	Field supplies	72.30
6	8	Pay roll	Services	307.30
6	9	....do	....do	228.00
6	10	....do	....do	237.90
6	11	....do	....do	42.00
6	12	Van H. Manning	Traveling expenses	60.85
6	13	Geo. T. Hawkins	Field expenses	57.40
6	14	H. L. Baldwin, jr	....do	73.94
7	15	Frank Smith	Field supplies	130.71
7	16	....do	....do	80.30
7	17	....do	....do	53.55
7	18	....do	....do	30.80
8	19	J. M. Zike	Lodging	7.50
9	20	Robert A. Farmer	Traveling expenses	52.30
9	21	D. C. Harrison	....do	75.45
9	22	W. T. Culbertson	Field material	50.65
9	23	S. S. Gannett	Field expenses	45.51
9	24	S. A. Cambron	Shoeing animals	66.25
9	25	W. M. Radecker	1 gelding	50.00
18	26	R. M. Towson	Traveling expenses	55.25
10	27	C. H. Fitch	....do	49.60
10	28	....do	....do	19.90
10	29	F. D. Blackman, agent	Freight	25.94
10	30	H. F. Schreiner	Field material	17.75
10	31	W. H. Cooper	....do	20.50
11	32	G. E. Cravens	....do	12.75
11	33	G. A. Cobb & Co	Field supplies	79.95
11	34	Geo. T. Hawkins	Field expenses	74.44
11	35	J. J. Belford	2 horses	90.00
11	36	R. O. Gordon	Field expenses	40.25
11	37	Van H. Manning	....do	102.85
11	38	Frank Smith	Field supplies	122.97
11	39	....do	Field material	60.86
11	40	G. E. Cravens	....do	7.50
11	41	H. F. Schreiner	....do	19.50
11	42	J. L. Farmer	....do	7.00
11	43	....do	....do	4.00
11	44	J. H. Ward	....do	26.90
11	45	Frank Smith	Field supplies	89.92
11	46	....do	....do	73.90
11	47	Robert A. Farmer	Field expenses	50.44
11	48	Frank Smith	Field supplies	132.75
11	49	....do	....do	122.97
14	50	P. H. Wilhelm	Board and lodging	15.75
28	51	H. C. Rizer	Traveling expenses	147.00
17	52	Frank Smith	Field material	60.12
17	53	....do	Field supplies	78.03
18	54	A. Ramel	Services	50.00
18	55	R. O. Gordon	Field expenses	45.50
18	56	Frank Smith	Material and supplies	35.67
20	57	J. L. Farmer	....do	5.35
20	58	Frank Smith	Supplies	122.97
20	59	Allen & Austen	Material	5.00
20	60	J. H. Ward	....do	9.60
20	61	E. F. Cain	....do	9.00
20	62	W. J. Crocker	Labor and material	6.10

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

MAY, 1895—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
May	20	63	G. E. Cravens	Field material	$16.70
	20	64	Frank Smith	do	104.36
	21	65	S. S. Gannett	Field expenses	64.45
	25	66	Robert A. Farmer	do	67.90
	27	67	Van H. Manning	do	49.98
	28	68	Frank Smith	Field supplies	71.76
	28	69	do	do	57.80
	28	70	do	do	65.19
	31	71	Van H. Manning	Services	119.20
	31	72	Pay roll	do	431.24
	31	73	do	do	466.20
	31	74	do	do	541.76
	31	75	do	do	27.09
	31	76	do	do	140.00
	31	77	do	do	480.85
	31	78	do	do	10.96
	31	79	do	do	293.00
	31	80	do	do	239.20
	31	81	do	do	536.93
	31	82	do	do	31.61
	31	83	S. S. Gannett	do	170.40
	31	84	Chas. Ellet Cabell	do	11.61
	31	85	Pay roll	do	422.63
	31	86	do	do	332.63
	31	87	R. M. Towson	Field expenses	50.35
	31	88	Wm. J. Peters	do	22.95
	31	89	S. S. Gannett	do	40.47
	31	90	W. H. Ainsworth	Field supplies	46.45
	31	91	Frank Smith	do	9.75
	31	92	Choctaw, Oklahoma & Gulf R. R. Co.	Rent of storage room	27.50
	31	93	J. M. Zike	Rent of office	7.50
	31	94	Robt. A. Farmer	Field expenses	106.88
	31	95	Henry C. F. Hackbush	Services	61.28
	31	96	S. S. Shapard	Field supplies	23.03
	31	97	R. E. Albright	do	7.35
	31	98	John W. Ridenour	Hire of livery team	40.00
			Total		15,958.71

JUNE, 1895.

June	4	1	C. H. Fitch	Field expenses	$20.54
	5	2	Pay roll	Services	380.81
	8	3	G. A. Cobb & Co	Field supplies	68.80
	8	4	Chas. F. Urquhart	Field expenses	4.00
	8	5	do	do	150.18
	10	6	H. L. Baldwin, jr	do	185.56
	10	7	C. H. Fitch	Traveling expenses	3.85
	10	8	do	do	5.10
	11	9	S. S. Gannett	Field expenses	38.25
	11	10	Van H. Manning	do	38.30
	12	11	Frank Smith	Field supplies	117.82
	12	12	do	Field material	26.62
	14	13	D. C. Harrison	Field expenses	87.97
	14	14	R. O. Gordon	do	127.75

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

JUNE, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
June 14	15	Robt. A. Farmer	Field expenses	$135.12
22	16	S. S. Gannett	do	133.40
22	17	William J. Peters	do	133.65
24	18	Henry Gannett	Traveling expenses	67.75
25	19	H. L. Baldwin	Field expenses	135.75
27	20	J. S. Welch	Field material	355.00
27	21	Emery, Bird, Thayer & Co	do	29.06
27	22	Sparks Bros	do	1,122.00
29	23	Pay roll	Services	461.90
29	24	do	do	328.30
29	25	do	do	400.66
29	26	do	do	629.90
29	27	do	do	659.40
29	28	do	do	60.00
29	29	do	do	741.40
29	30	do	do	304.80
29	31	do	do	235.40
29	32	do	do	555.40
29	33	do	do	180.00
29	34	Ole Quam	do	53.33
29	35	Pay roll	do	167.00
29	36	F. Weber's Sons	Field material	184.57
29	37	Frank Smith	Field supplies	50.84
29	38	W. T. Culbertson	do	133.34
29	39	Frank Smith	do	120.91
29	40	Robt. A. Farmer	Field expenses	131.98
29	41	G. A. Cobb & Co	Field supplies	157.80
29	42	Geo. T. Hawkins	Field expenses	127.39
29	43	Frank Smith	Field material	5.55
29	44	J. M. Zike	Office rent	7.50
29	45	R. E. Albright	Field supplies	11.60
29	46	Pay roll	Services	437.90
29	47	do	do	406.90
29	48	Van H. Manning	Field expenses	153.22
29	49	Pay roll	Services	51.66
29	50	D. C. Harrison	Field expenses	382.41
29	51	E. A. Robinson	Field supplies	122.94
29	52	S. S. Shapard	do	42.62
29	53	C. H. Fitch	Traveling expenses	24.80
29	54	Frank Smith	Field supplies	102.40
29	55	do	do	68.40
29	56	R. O. Gordon	Field expenses	132.45
29	57	L. R. Tenbirer	Services	7.00
29	58	J. M. Piburn	do	7.00
		Total		11,015.98

JULY, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
July 9	1	C. H. Fitch	Field expenses	$61.99
9	2	Choctaw, Oklahoma & Gulf R. R. Co.	Rent or storeroom	15.00
9	3	S. S. Gannett	Field expenses	99.37
9	4	Robt. A. Farmer	do	23.42
9	5	F. J. Gordon	Services	3.00
10	6	Chas. Urquhart	Field expenses	181.95

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

JULY, 1895—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
July	10	7	H. L. Baldwin	Field expenses	$153.81
	11	8	Jeremiah Ahern	do	27.03
	11	9	Riley Alverson	Field supplies	51.25
	11	10	Grady & Freeny	do	52.20
	11	11	Frank Smith	Field material	17.23
	11	12	do	do	19.05
	13	13	do	do	22.95
	12	14	do	Field supplies	36.35
	12	15	C. H. Fitch	Traveling expenses	51.85
	13	16	Chas. E. Cooke	do	18.75
	13	17	W. H. Ainsworth	Field material	147.78
	13	18	Wm. J. Peters	Field expenses	102.60
	15	19	R. M. Towson	do	94.16
	16	20	Robt. A. Farmer	do	102.96
	16	21	do	do	6.85
	16	22	Chas. E. Cooke	do	77.79
	18	23	Geo. T. Hawkins	do	41.30
	20	24	S. S. Gannett	do	66.87
	20	25	E. A. Robinson	Field supplies	112.68
	22	26	do	do	2.50
	22	27	Hay & Hais	Field material	11.05
	22	28	H. Bates	do	17.10
	22	29	B. F. Bryant	do	21.85
	22	30	E. P. G. Hunter	do	21.20
	23	31	W. H. Ainsworth	Field supplies	31.48
	23	32	Riley Alverson	Field material	3.60
	31	33	Pay roll	Services	440.60
	31	34	do	do	704.35
	31	35	do	do	694.80
	31	36	do	do	120.32
	31	37	do	do	164.53
	31	38	do	do	1,336.08
	31	39	Bloom Berry	do	17.00
	31	40	Pay roll	do	164.80
	31	41	do	do	697.90
	31	42	do	do	394.80
	31	43	do	do	331.60
	31	44	Maggie M. Loeffler	do	60.00
	31	45	S. S. Gannett	do	168.50
	31	46	Chas. E. Cooke	Field expenses	105.99
	31	47	Van H. Manning	do	145.13
	31	48	Pay roll	Services	283.36
	31	49	do	do	496.20
	31	50	do	do	395.00
	31	51	Robt. A. Farmer	Field expenses	106.28
	31	52	E. A. Robinson	Field supplies	140.71
	31	53	Geo. T. Hawkins	Field expenses	167.76
	31	54	H. L. Baldwin, jr	do	165.52
	31	55	D. C. Harrison	do	358.11
			Total		9,689.31

AUGUST, 1895.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Aug.	7	1	Chas. E. Cooke	Field expenses	$32.20
	7	2	H. L. Baldwin, jr	do	116.70
	9	3	Chas. E. Cooke	do	96.72

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

AUGUST, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Aug. 9	4	Geo. T. Hawkins	Field expenses	$204.97
9	5	do	Traveling expenses	5.25
10	6	Robt. A. Farmer	Field expenses	124.15
12	7	Pay roll	Services	453.17
12	8	Chas. F. Urquhart	Field expenses	261.14
19	9	Jeremiah Ahern	do	114.63
20	10	Robt. A. Farmer	do	50.89
20	11	H. L. Baldwin, jr	do	104.56
20	12	Chas. E. Cooke	do	124.57
20	13	R. M. Towson	do	124.49
20	14	Van H. Manning	do	144.97
21	15	R. O. Gordon	do	219.88
21	16	William J. Peters	do	82.91
21	17	Frank Smith	Field supplies	67.95
21	18	do	do	17.92
21	19	do	do	84.76
22	20	H. Bates	do	87.20
22	21	W. H. Ainsworth	do	164.96
22	22	do	do	83.16
24	23	J. M. Zike	Office rent	11.25
24	24	J. H. Peter	Field supplies	8.25
24	25	Frank Smith	Storage	15.00
24	26	S. S. Shapard	Field supplies	51.36
26	27	C. H. Fitch	Field expenses	35.62
31	28	do	Traveling expenses	16.55
31	29	Frank Middleton	Services	21.29
31	30	Pay roll	do	440.60
31	31	do	do	726.09
31	32	do	do	374.80
31	33	do	do	376.28
31	34	do	do	487.90
31	35	do	do	231.61
31	36	do	do	697.90
31	37	do	do	340.00
31	38	Van H. Manning	Field expenses	136.02
31	39	G. B. Hester	Field supplies	146.88
31	40	Pay roll	Services	421.60
31	41	do	do	1,322.54
31	42	do	do	364.80
31	43	Robt. A. Farmer	Field expenses	145.37
31	44	Pay roll	Services	449.67
31	45	do	do	395.00
31	46	do	do	404.80
		Total		10,388.33

SEPTEMBER, 1895.

Sept. 7	1	H. L. Baldwin, jr	Field expenses	$168.95
7	2	Chas. E. Cooke	do	115.06
9	3	D. C. Harrison	do	342.91
9	4	John E. Kelly	Services	8.61
9	5	H. A. Neeley	do	8.61
9	6	Robt. A. Farmer	Field expenses	32.55
9	7	Geo. T. Hawkins	do	239.68
10	8	C. H. Fitch	do	43.88
10	9	Chas. F. Urquhart	do	303 32

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

SEPTEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 10	10	Van H. Manning	Field expenses	$150.30
11	11	J. R. McMurtrey	Services	30.00
11	12	S. S. Shapard	Field supplies	42.61
14	13	Felix R. Phillips	do	106.16
14	14	A. M. Russell	Field material	25.00
14	15	Frank Smith	do	89.74
14	16	do	Storage	15.00
14	17	do	Field supplies	263.50
14	18	do	do	118.16
14	19	O. M. Burtnett	Field material	18.70
14	20	Geo. Norton	do	13.00
14	21	H. F. Schreiner	do	16.50
14	22	Frank Smith	do	75.42
21	23	Robert Coe	Services	33.33
21	24	E. Ellis	do	15.00
21	25	Robt. A. Farmer	Field expenses	154.14
26	26	Jeremiah Ahern	do	149.49
26	27	Wm. A. Peters	do	165.07
26	28	Chas. E. Cooke	do	77.65
26	29	R. O. Gordon	do	261.17
27	30	J. S. Welch	Field material	236.50
27	31	Frank Smith	do	4.51
27	32	do	Field supplies	63.50
27	33	H. L. Baldwin, jr	Field expenses	165.33
30	34	Pay roll	Services	483.80
30	35	do	do	430.40
30	36	do	do	1,286.73
30	37	do	do	824.86
30	38	do	do	340.00
30	39	do	do	300.40
30	40	do	do	385.00
30	41	do	do	509.00
30	42	do	do	66.33
30	43	do	do	579.86
30	44	do	do	310.20
30	45	S. N. Stoner	do	14.00
30	46	W. P. Rogers	do	26.00
30	47	Chas. E. Cooke	Field expenses	170.15
30	48	Frank Smith	Field material	11.90
30	49	do	do	38.55
30	50	do	do	50.15
30	51	H. F. Schreiner	do	11.75
30	52	Pay roll	Services	392.80
30	53	do	do	491.80
30	54	Geo. W. Hoper	do	8.00
30	55	Pay roll	do	1,098.06
		Total		11,385.73

OCTOBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Oct. 5	1	Van H. Manning	Field expenses	$301.70
8	2	Chas. F. Urquhart	do	178.30
9	3	C. H. Fitch	do	106.21
9	4	Robt. A. Farmer	do	100.75
9	5	William J. Peters	do	142.22
9	6	Chas. E. Cooke	do	44.20

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

OCTOBER, 1895—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Oct.	9	7	S. S. Shapard	Field supplies	$48.19
	9	8	Frank Smith	......do	314.48
	9	9	......do	Storage	15.00
	9	10	......do	Field material	95.18
	10	11	D. C. Harrison	Field expenses	522.45
	10	12	Pay roll	Services	301.40
	10	13	Geo. T. Hawkins	Field expenses	255.89
	12	14	H. L. Baldwin, jr	......do	89.97
	14	15	Frank Smith	Field supplies	125.30
	14	16	J. F. Hervey	Services	4.84
	15	17	A. E. Johnson	......do	6.00
	18	18	R. M. Towson	Field expenses	165.82
	18	19	Van H. Manning	......do	209.95
	18	20	B. H. Hester	Services	19.58
	19	21	R. O. Gordon	Field expenses	156.95
	22	22	Robt. A. Farmer	......do	135.98
	22	23	G. B. Hester	Field supplies	44.72
	22	24	A. M. Russell	Field material	16.70
	22	25	H. Bates	......do	17.40
	23	26	W. H. Ainsworth	......do	112.60
	23	27	R. M. Towson	Field expenses	150.27
	26	28	Frank Smith	Field supplies	60.35
	31	29	Pay roll	Services	537.04
	31	30	......do	......do	471.57
	31	31	......do	......do	582.54
	31	32	......do	......do	274.80
	31	33	......do	......do	1,329.83
	31	34	......do	......do	357.90
	31	35	......do	......do	1,318.21
	31	36	......do	......do	1,434.50
	31	37	Chas. E. Cooke	Field expenses	85.85
	31	38	Pay roll	Services	1,298.97
	31	39	......do	......do	395.00
	31	40	......do	......do	336.87
	31	41	......do	......do	408.03
	31	42	W. C. Oldham	......do	12.88
	31	43	H. L. Baldwin, jr	Field expenses	209.53
	31	44	Jeremiah Ahern	......do	171.13
	31	45	Grimm & Flynn	Field material	22.50
	31	46	......do	Field supplies	82.83
	31	47	......do	......do	71.90
			Total		13,144.28

NOVEMBER, 1895.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Nov.	6	1	Robt. A. Farmer	Field expenses	$83.25
	6	2	C. H. Fitch	......do	110.56
	6	3	Van H. Manning	......do	243.83
	7	4	Geo. T. Hawkins	......do	255.79
	7	5	S. S. Shapard	Field supplies	318.73
	7	6	......do	Field material	88.90
	8	7	......do	Field supplies	32.92
	8	8	Frank Smith	Field material	23.70
	8	9	......do	Storage	15.00
	8	10	Alexander Haas	Field supplies	156.83

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

NOVEMBER, 1895—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Nov.	8	11	W. H. Ainsworth	Field supplies	$70.37
	8	12	Felix R. Phillips	do	129.43
	9	13	Chas. E. Cooke	Field expenses	163.65
	11	14	Frank Smith	Field supplies	138.10
	11	15	Jeremiah Ahern	Field expenses	114.35
	15	16	D. C. Harrison	do	516.43
	15	17	Wm. J. Peters	do	76.65
	15	18	H. C. Hall & Co	Field supplies	71.30
	15	19	E. B. Bunker	Services	7.73
	15	20	do	do	4.00
	16	21	R. M. Towson	Field expenses	233.00
	19	22	Chas. F. Urquhart	do	172.37
	21	23	W. B. Corse	Traveling expenses	17.80
	22	24	C. H. Fitch	do	68.80
	22	25	Dave Winbray	Services	6.00
	27	26	Van H. Manning	Field expenses	295.63
	27	27	Robt. A. Farmer	do	181.07
	27	28	L. H. Baldwin, jr	do	82.29
	27	29	H. F. Schreiner	Field material	22.25
	29	30	Jack Harvey	Services	22.00
	30	31	W. K. Blachly	do	20.32
	30	32	Pay roll	do	731.30
	30	33	do	do	345.20
	30	34	do	do	441.80
	30	35	do	do	1,289.40
	30	36	do	do	1,332.60
	30	37	do	do	1,426.24
	30	38	J. G. Pollock	do	3.87
	30	39	Fred S. McIntyre	Office rent	6.00
	30	40	Frank Smith	Storage	15.00
	30	41	Chas. E. Cooke	Field expenses	261.78
	30	42	Pay roll	Services	349.80
	30	43	do	do	488.40
	30	44	do	do	270.40
	30	45	do	do	1,288.46
	30	46	Van H. Manning	Field expenses	135.67
	30	47	Geo. T. Hawkins	do	342.67
	30	48	S. S. Shapard	Field supplies	263.02
			Total		12,743.66

DECEMBER, 1895.

Dec.	5	1	Frank Smith	Field supplies	$135.47
	5	2	S. S. Shapard	do	27.25
	5	3	Frank Smith	Field expenses	21.20
	5	4	C. H. Fitch	do	123.78
	11	5	Pay roll	Services	384.00
	11	6	do	do	405.40
	11	7	C. W. Goodlove	Traveling expenses	36.55
	12	8	Frank Smith	Field suppliss	123.45
	12	9	R. M. Towson	Field expenses	126.10
	13	10	D. C. Harrison	do	559.71
	13	11	H. C. Rizer	do	6.00
	14	12	S. Crowl	Field material	21.80

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

DECEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Dec. 14	13	R. M. Towson	Field expenses	$18.50
14	14	Chas. E. Cooke	do	98.36
14	15	Jeremiah Ahern	do	140.79
14	16	Robert A. Farmer	do	112.31
14	17	H. L. Baldwin, jr	do	237.94
16	18	R. M. Towson	Traveling expenses	47.40
16	19	Chas. F. Urquhart	Field expenses	149.65
17	20	Robt. A. Farmer	do	79.80
17	21	D. C. Harrison	Traveling expenses	56.75
17	22	J. R. Wood	Services	8.70
17	23	H. C. Hall & Co	Field supplies	35.75
17	24	do	do	20.01
17	25	Hugo Haas	do	228.16
18	26	H. Haas	do	140.35
18	27	Van H. Manning	Field expenses	147.56
19	28	G. L. Hooker	Services	14.50
19	29	W. B. Corse	Field expenses	246.35
23	30	Chas. E. Cooke	do	160.14
24	31	U. L. Berry	Services	14.52
24	32	Henry Boon	do	18.39
24	33	Walter Clifton	do	14.52
24	34	W. G. Mathies	do	14.52
24	35	J. M. Fawbush	do	14.52
27	36	Geo. T. Hawkins	Field expenses	174.51
27	37	Robt. A. Farmer	do	102.07
27	38	S. R. Fraser	Services	5.00
27	39	Van H. Manning	Traveling expenses	63.50
27	40	Geo. T. Hawkins	do	49.00
31	41	Pay roll	Services	561.73
31	42	do	do	233.05
31	43	do	do	1,149.92
31	44	do	do	332.09
31	45	Jas. E. Shelley	do	51.61
31	46	Sledge Tatum	do	45.16
31	47	D. B. Porter	Care of stock	23.00
31	48	Alex. Sellers	Shoeing stock	13.00
31	49	D. C. Harrison	Services	134.80
31	50	G. T. Hawkins	do	134.80
31	51	Pay roll	do	376.92
31	52	R. M. Towson	do	117.90
31	53	Pay roll	do	1,287.85
31	54	do	do	570.91
31	55	do	do	559.01
31	56	W. C. Oldham	do	12.88
31	57	Pay roll	do	1,191.10
31	58	H. L. Baldwin, jr	do	151.60
31	59	Pay roll	do	507.73
31	60	do	do	559.32
31	61	do	do	434.80
31	62	F. E. Joy	do	20.97
31	63	J. A. McCormick	do	21.29
31	64	Sparks Bros	Stock and feed	1,914.88
31	65	James I. Crothers	Supplies	76.55
31	66	S. S. Shapard	do	57.94
31	67	Fred. S. McIntyre	Office rent	15.00
		Total		14,640.12

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

JANUARY, 1896.

Date of payment.		No of voucher.	To whom paid.	For what paid.	Amount.
Jan.	10	1	R. I. Merrifield	Services	$30.00
	10	2	C. A. Martin	.....do	12.90
	10	3	Robt. A. Farmer	Traveling expenses	60.05
	10	4	H. L. Baldwin, jr	.....do	49.80
	10	5	D. C. Harrison	.....do	51.00
	10	6	Van H. Manning	.....do	18.50
	10	7	Frank Smith	Storage	15.00
	10	8	J. H. Foster	Supplies	18.35
	11	9	Chas. F. Urquhart	Field expenses	159.83
	11	10	C. H. Fitch	.....do	129.99
	13	11	Van H. Manning	.....do	210.46
	14	12	W. A. Lindsay	.....do	200.01
	15	13	M. P. McCoy	.....do	86.70
	15	14	W. A. Lindsay	.....do	8.00
	16	15	William J. Peters	.....do	129.99
	16	16	.....do	.....do	177.64
	16	17	C. W. Goodlove	.....do	463.50
	16	18	Chas. E. Cooke	.....do	170.07
	16	19	.....do	.....do	155.21
	17	20	R. O. Gordon	.....do	91.95
	18	21	Van H. Manning	.....do	240.33
	18	22	Jeremiah Ahern	.....do	132.99
	18	23	Pay roll	Services	380.48
	18	24	Walter Clifton	.....do	7.74
	18	25	F. Weber's Sons	Field materials	341.82
	18	26	A. S. Johnson	Services	7.74
	18	27	S. S. Shapard	Supplies	207.39
	18	28	W. H. Ainsworth	.....do	188.57
	20	29	Frank Ainsworth	.....do	138.22
	20	30	W. B. Corse	Field expenses	165.77
	21	31	C. D. Kelly	Supplies	125.82
	21	32	Kenffel Esser Co	Material	11.70
	21	33	C. J. Baker	.....do	765.24
	21	34	Chas. E. Cooke	Traveling expenses	50.40
	23	35	Henry Collins	Services	18.39
	24	36	W. B. Corse	Field expenses	153.47
	24	37	J. M. Hall & Co	Supplies	70.67
	25	38	.....do	Material	56.15
	25	39	Tholen Bros	.....do	18.00
	31	40	Pay roll	Services	1,343.87
	31	41	.....do	.....do	617.90
	31	42	.....do	.....do	378.55
	31	43	.....do	.....do	408.55
	31	44	.....do	.....do	477.48
	31	45	J. Scott Harrison	.....do	25.80
	31	46	Pay roll	.....do	276.30
	31	47	Geo. T. Hawkins	.....do	136.30
	31	48	Robt. A. Farmer	.....do	119.20
	31	49	Chas. S. Guy	.....do	14.52
	31	50	Chas. E. Cooke	.....do	119.20
	31	51	H. L. Baldwin, jr	.....do	153.30
	31	52	Pay roll	.....do	1,439.52
	31	53	.....do	.....do	317.71
	31	54	.....do	.....do	408.20
	31	55	W. & L. E. Gurley	Material	107.16
	31	56	J. W. Goodman	Supplies	41.75
	31	57	Robt. A. Farmer	Field expenses	165.00
	31	58	R. O. Gordon	.....do	233.75

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

JANUARY, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Jan.	31	59	Pay roll	Services	$763.69
	31	60	.....do	.....do	419.02
	31	61	.....do	.....do	53.22
	31	62	Hibbard Bros	Field supplies	77.22
			Total		13,417.04

FEBRUARY, 1896.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Feb.	4	1	Robt. A. Farmer	Traveling expenses	$52.00
	4	2	Jas. L. Johnson	Field expenses	7.30
	6	3	W. C. Oldham	Services	12.88
	6	4	Van H. Manning	Field expenses	297.30
	8	5	Chas. F. Urquhart	.....do	149.12
	10	6	C. H. Fitch	.....do	84.80
	10	7	D. C. Harrison	.....do	629.37
	11	8	Jeremiah Ahern	.....do	120.82
	11	9	R. O. Gordon	.....do	142.25
	11	10	M. P. McCoy	.....do	256.89
	12	11	W. A. Lindsay	.....do	219.81
	12	12	W. B. Corse	.....do	212.10
	13	13	Pay roll	Services	420.16
	13	14	Fred S. McIntyre	Office rent	15.00
	13	15	Jno. B. Riley	Storage	15.00
	13	16	J. H. Foster	Supplies	26.30
	13	17	Jno. B. Riley	.....do	137.51
	13	18	Frank Smith	.....do	48.14
	13	19	S. S. Shapard	.....do	24.65
	13	20	.....do	Material	11.61
	13	21	Foley & Tully	Material and supplies	265.64
	13	22	James I. Crothers	Material	34.54
	13	23	C. J. Baker	.....do	29.92
	14	24	Pay roll	Services	1,129.67
	15	25	M. P. McCoy	Field expenses	196.20
	17	26	Van H. Manning	.....do	195.89
	17	27	Ole Quam	Services	12.90
	17	28	J. V. Johnson	.....do	9.30
	18	29	W. & L. E. Gurley	Instruments	51.42
	18	30	Hibbard Bros	Supplies	75.97
	20	31	Robt. A. Farmer	Field expenses	119.44
	24	32	J. Burdett	Material	29.11
	25	33	Chas. F. Urquhart	Field expenses	155.45
	25	34	Hibbard Bros	Supplies	111.90
	25	35	Walter Clifton	Services	14.48
	29	36	Pay roll	.....do	473.40
	29	37	.....do	.....do	1,251.22
	29	38	.....do	.....do	842.98
	29	39	.....do	.....do	381.60
	29	40	Geo. T. Hawkins	.....do	127.40
	29	41	Chas. E. Cooke	.....do	111.60
	29	42	H. L. Baldwin, jr	.....do	143.40
	29	43	Pay roll	.....do	405.34
	29	44	.....do	.....do	753.08
	29	45	.....do	.....do	668.75
	29	46	.....do	.....do	1,382.21
	29	47	R. O. Gordon	Field expenses	187.55

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

FEBRUARY, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Feb. 29	48	Robt. A. Farmer	Field expenses	$148.43
29	49	Pay roll	Services	1,565.57
		Total		13,757.37

MARCH, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Mar. 6	1	Pay roll	Services	$427.40
7	2	.....do	.....do	387.75
7	3	Comar & Evans	Supplies	56.89
7	4	S. S. Shapard	.....do	105.91
7	5	J. H. Foster	.....do	28.20
7	6	John B. Riley	.....do	29.05
7	7	Fred S. McIntyre	Office rent	15.00
7	8	John B. Riley	Storage	15.00
7	9	Curran & Lamb	Material	34.00
9	10	Pay roll	Services	423.96
9	11	W. A. Lindsay	Field expenses	170.26
10	12	C. H. Fitch	.....do	140.22
11	13	M. P. McCoy	.....do	83.74
11	14	Robt. A. Farmer	.....do	178.02
10	15	Van H. Manning	.....do	212.58
13	16	A. M. Johnson	Services	6.20
13	17	Nathan Bolens	.....do	14.51
16	18	Chas. F. Urquhart	Field expenses	498.97
16	19	W. B. Corse	.....do	390.00
16	20	Lafayette & Bro	Supplies and material	345.05
16	21	C. N. Judd	Material	14.25
16	22	Frank Lewis	Services	51.72
17	23	C. W. Holmes	.....do	8.70
18	24	D. C. Harrison	Field expenses	506.15
21	25	Jeremiah Ahern	.....do	123.55
23	26	Van H. Manning	.....do	168.79
23	27	William J. Peters	.....do	265.95
24	28	R. F. Scott Grocery Co	Supplies	38.83
24	29	D. C. Harrison	Field expenses	67.35
28	30	Robt. A. Farmer	.....do	172.83
28	31	J. M. Piburn	Services	11.61
31	32	Pay roll	.....do	732.90
31	33	.....do	.....do	389.20
31	34	.....do	.....do	1,278.69
31	35	.....do	.....do	429.02
31	36	Geo. T. Hawkins	.....do	136.30
31	37	H. L. Baldwin, jr	.....do	153.30
31	38	William J. Peters	.....do	153.30
31	39	Chas. E. Cooke	.....do	119.20
31	40	Pay roll	.....do	155.14
31	41	.....do	.....do	1,408.70
31	42	.....do	.....do	425.00
31	43	.....do	.....do	1,417.10
31	44	Robt. A. Farmer	Field expenses	78.27
31	45	J. B. Riley	Storage	15.00
31	46	Fred S. McIntyre	Office rent	15.00
31	47	Pay roll	Services	419.94
31	48	Fred Watts, jr	.....do	29.00
31	49	.....do	.....do	12.58
		Total		12,360.08

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

APRIL, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Apr. 6	1	S. S. Shapard	Supplies	$118.61
6	2	Pay roll	Services	424.99
6	3	C. H. Fitch	Field expenses	97.63
7	4	Pay roll	Services	1,510.14
8	5	C. H. Fitch	Traveling expenses	48.15
8	6	W. A. Lindsay	Field expenses	205.40
8	7	W. T. Turner	Services	35.48
9	8	D. C. Harrison	Field expenses	526.38
9	9	J. H. Brazell	Hire of team	38.00
10	10	Pay roll	Services	419.18
10	11	M. P. McCoy	Field expenses	266.38
10	12	.....do	.....do	7.80
11	13	William J. Peters	Traveling expenses	15.00
14	14	W. B. Corse	Field expenses	734.41
14	15	Wm. B. Douglass	Services	23.33
14	16	J. Scott Harrison	Field expenses	80.25
14	17	J. H. Foster	Supplies	34.30
14	18	F. W. Alvord	Field expenses	94.86
15	19	William J. Peters	.....do	236.47
15	20	.....do	.....do	33.75
15	21	Chas. F. Urquhart	.....do	729.18
16	22	Van H. Manning	.....do	183.06
16	23	R. O. Gordon	.....do	187.20
16	24	Jeremiah Ahearn	.....do	155.64
16	25	Brady Bros. & Co	Supplies	118.51
20	26	F. W. Alvord	Field expenses	102.62
21	27	F. G. McConnell	Services	6.77
21	28	C. H. Fitch	Traveling expenses	19.35
21	29	C. E. Cooke	.....do	14.15
20	30	A. M. Johnson	Services	14.00
20	31	Jos. A. Carr	.....do	12.00
20	32	C. H. Underwood	.....do	8.00
21	33	La Fayette & Bro	Supplies	192.31
24	34	R. F. Scott Grocery Co	.....do	18.60
24	35	J. H. Keith	Services	8.00
25	36	Van H. Manning	Field expenses	170.60
25	37	Robt. A. Farmer	.....do	14.10
25	38	.....do	.....do	152.84
30	39	Pay roll	Services	966.40
30	40	.....do	.....do	355.40
30	41	.....do	.....do	1,356.90
30	42	Geo. T. Hawkins	.....do	131.90
30	43	H. L. Baldwin, jr	.....do	148.30
30	44	Pay roll	.....do	460.00
30	45	.....do	.....do	1,399.90
30	46	.....do	.....do	1,345.10
30	47	William J. Peters	.....do	148.30
30	48	F. W. Alvord	.....do	98.67
30	49	Tholen Bros	Material	25.00
30	50	Pay roll	Services	431.90
30	51	.....do	.....do	1,428.90
		Total		15,354.17

MAY, 1896.

May 4	1	Pay roll	Services	$295.00
4	2	E. N. Ratliff & Co	Supplies	91.30

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

MAY, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
May	4	3	W. M. Keith	Supplies	$275.90
	4	4	R. F. Scott Grocery Co	....do	95.03
	5	5	R. O. Gordon	Field expenses	224.75
	5	6	Robt. A Farmer	....do	112.71
	5	7	Van H. Manning	....do	137.63
	5	8	C. H. Fitch	....do	61.20
	6	9	J. H. Foster	Supplies	22.75
	6	10	J. B. Riley	....do	45.85
	6	11	....do	Storage	15.00
	6	12	S. S. Shapard	Supplies	122.30
	7	13	Brady Bros. & Co	....do	268.41
	8	14	Pay roll	Services	399.00
	9	15	W. B. Corse	Field expenses	258.35
	12	16	J. N. Jackson	Services	1.94
	12	17	Pay roll	....do	425.00
	12	18	W. A. Lindsay	Field expenses	190.56
	12	19	F. W. Alvord	....do	15.37
	13	20	J. Scott Harrison	....do	118.32
	13	21	D. C. Harrison	....do	364.44
	14	22	Chas. F. Urquhart	....do	731.85
	14	23	Jeremiah Ahern	....do	157.05
	15	24	Holmes Conrad, jr	Services	7.74
	16	25	Robt. A. Farmer	Field expenses	132.31
	22	26	Van H. Manning	....do	192.35
	23	27	M. P. Lyon	Services	12.58
	23	28	R. F. Scott Grocery Co	Supplies	35.69
	25	29	Fred S. McIntyre	Office rent	15.00
	29	30	Pay roll	Services	395.55
	29	31	William J. Peters	....do	153.40
	29	32	Geo. T. Hawkins	....do	136.20
	29	33	Pay roll	....do	1,029.20
	29	34	H. L. Baldwin, jr	....do	153.40
	29	35	Pay roll	....do	1,365.49
	29	36	Paul McKennon	....do	19.35
	29	37	J. R. Bradley	Material	73.00
	29	38	R. O. Gordon	Field expenses	217.85
	29	39	....do	....do	142.20
			Total		8,511.02

JUNE, 1896.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
June	2	1	Pay roll	Services	$1,439.43
	2	2	....do	....do	477.26
	3	3	....do	....do	1,404.75
	4	4	....do	....do	422.65
	4	5	G. H. Hinton	....do	19.35
	4	6	J. R. Bradley	Rent of office	25.00
	4	7	....do	Rent of storage room	15.00
	4	8	....do	Supplies	42.82
	5	9	S. S. Shapard	....do	61.00
	5	10	J. H. Foster	....do	23.65
	5	11	Pay roll	Services	280.00
	6	12	....do	....do	1,400.88
	8	13	....do	....do	366.92
	8	14	....do	....do	455.00

Abstract of disbursements made by H. C. Rizer, special disbursing agent, United States Geological Survey, etc.—Continued.

SURVEYING LANDS IN THE INDIAN TERRITORY, 1895 AND 1896—Continued.

JUNE, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
June	9	15	Brady Bros. & Co	Supplies	$135.94
	9	16	W. G. Gibbons & Co	......do	143.97
	9	17	H. & A. Hass	......do	84.33
	9	18	C. H. Fitch	Field expenses	134.83
	9	19	W. B. Corse	......do	375.35
	9	20	J. Scott Harrison	......do	108.53
	10	21	Robt. A. Farmer	......do	117.89
	10	22	D. C. Harrison	......do	755.59
	11	23	Van H. Manning	......do	170.44
	11	24	F. W. Alvord	......do	127.48
	12	25	W. A. Lindsay	......do	316.98
	13	26	J. R. Bradley	Supplies	71.00
	13	27	R. O. Gordon	Field expenses	44.43
	13	28	Jeremiah Ahern	......do	167.26
	13	29	Robt. A. Farmer	......do	66.35
	15	30	Charles F. Urquhart	......do	475.09
	20	31	F. W. Alvord	......do	201.22
	22	32	H. L. Baldwin, jr	Services	49.45
	26	33	Pay roll	......do	270.29
	26	34	C. H. Fitch	Field expenses	18.63
	26	35	J. R. Bradley	Office rent	8.33
	26	36	......do	Storage	5.00
	26	37	......do	Supplies	11.30
	26	38	Pay roll	Services	59.45
	27	39	S. S. Shapard	Supplies	21.54
	27	40	J. H. Foster	......do	8.30
	27	41	F. W. Alvord	Field expenses	17.25
	27	42	Pay roll	Services	51.66
	30	43	......do	......do	53.96
	30	44	W. B. Corse	Field expenses	33.05
	30	45	J. A. McCormick	Services	4.00
	30	46	Pay roll	......do	53.96
	30	47	......do	......do	43.33
	30	48	J. Scott Harrison	Field expenses	9.38
	30	49	Van H. Manning	......do	30.90
	30	50	M. P. McCoy	Services	41.67
	30	51	Pay roll	......do	675.87
	30	52	L. H. Baldwin, jr	Traveling expenses	16.00
	30	53	Redick H. McKee	......do	14.50
	30	54	Pay roll	Services	219.91
	30	55	Redick H. McKee	......do	131.90
	30	56	J. H. Wilson	......do	8.00
	30	57	Sam Threlkeld	......do	8.00
	30	58	H. F. Schreiner	Material	8.10
	30	59	D. C. Harrison	Field expenses	107.60
	30	60	Jeremiah Ahern	......do	7.39
	30	61	Pay roll	Services	117.28
	30	62	......do	......do	33.00
	30	63	......do	......do	53.96
	30	64	Chas. F. Urquhart	......do	43.96
	30	65	Pay roll	......do	51.66
	30	66	W. A. Lindsay	Field expenses	22.76
	30	67	R. O. Gordon	......do	13.20
	30	68	J. L. Farmer	Labor	7.45
	30	69	J. R. Bradley	Material	14.72
			Total		12,277.12

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, from June 1, 1895, to June 30, 1896.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896.

JUNE, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
June 1	1	A. M. Walker	Traveling expenses	$9.82
14	2	.....do	Field expenses	63.57
14	3	W. J. Lloyd	.....do	12.50
19	4	R. U. Goode	Traveling expenses	65.60
18	5	Wm. H. Griffin	.....do	38.98
18	6	Basil Duke	.....do	17.75
18	7	Yode & Lewis	Supplies	105.80
18	8	Harrington & Knight	.....do	31.45
18	9	S. S. Hooper	Services, May 27, 31, 1895	9.67
18	10	R. B. Marshall	Field expenses	45.70
18	11	Frank Tweedy	.....do	82.75
18	12	W. M. Adams	Boarding, etc	31.00
18	13	J. W. Morehead	.....do	24.50
18	14	J. H. Wheat	Field expenses	26.50
19	15	J. H. Jennings	.....do	122.00
19	16	Magels & Co	Material	72.50
19	17	W. A. Bigelow	Hay	16.00
19	18	L. S. Hatcher	Shoeing	29.00
19	19	E. M. Douglas	Traveling expenses	60.25
24	20	A. H. Thompson	.....do	19.25
20	21	J. H. Jennings	.....do	8.11
20	22	James H. McCormick	.....do	18.55
20	23	Frank Sutton	Field expenses	57.00
21	24	Redick H. McKee	.....do	45.85
21	25	J. W. Thom	Traveling expenses	3.65
21	26	W. H. Otis	Field expenses	50.85
21	27	.....do	Boarding expenses	2.50
21	28	W. T. Walker	Care of stock	50.00
21	29	.....do	.....do	10.00
21	30	L. W. Estes	.....do	57.69
22	31	Chas. E. Cooke	Field expenses	30.10
29	32	Irving W. Bonbright	Storage	15.00
24	33	E. T. Perkins, jr	Field expenses	68.40
24	34	R. H. Chapman	.....do	81.32
29	35	R. B. Marshall	.....do	62.06
29	36	W. S. Post	.....do	156.02
29	37	Pay roll of employees	Services, June, 1895	298.90
29	38	.....do	.....do	274.96
29	39	.....do	.....do	363.50
24	40	F. H. Gorbon	Subsistence	45.38
24	41	Western Carriage Top Co	Buckboard tops	28.50
29	42	H. S. Wallace	Field expenses	27.95
29	43	J. H. Renshawe	Traveling expenses	39.10
19–29	44	.....do	Services, June, 1895	181.30
29	45	Pay roll of employees	.....do	339.30
29	46	.....do	.....do	365.30
29	47	.....do	.....do	322.30
29	48	.....do	Services, May, 1895	81.62
29	49	.....do	Services, June, 1895	316.00
29	50	.....do	.....do	319.60
29	51	L. C. Fletcher	Field expenses	54.41
29	52	.....do	.....do	143.02
29	53	Pay roll of employees	Services, June, 1895	214.30
29	54	.....do	.....do	231.90
29	55	.....do	.....do	306.10
29	56	Gilbert Thompson	.....do	164.80
29	57	W. M. Beaman	.....do	82.40
29	58	Spratlen & Anderson	Subsistence	34.90

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JUNE, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
June 29	59	Spartlen & Anderson	Material	$16.75
29	60	......do	......do	18.95
29	61	......do	......do	20.02
29	62	......do	Lumber	4.05
29	63	......do	Hay and oats	38.52
29	64	......do	Subsistence	25.44
29	65	Pay roll of employees	Services, June, 1895	115.40
29	66	......do	......do	253.73
29	67	......do	......do	321.10
29	68	......do	......do	174.20
29	69	......do	......do	281.90
29	70	J. L. Johnson	......do	69.20
29	71	J. H. Wheat	......do	74.20
29	72	Frank Tweedy	......do	148.30
29	73	J. Macfarland	......do	69.20
29	74	S. E. Cook	......do	34.50
29	75	Pay roll of employees	......do	221.90
29	76	......do	......do	247.30
29	77	Nat Tyler, jr	Field expenses	22.50
		Total		7,994.69

JULY, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
July 3	1	J. H. Wheat	Field expenses	$42.50
2	2	W. H. Lovell	......do	51.75
2	3	Frank Tweedy	......do	149.72
2	4	......do	Traveling expenses	25.00
3	5	H. M. Wilson	......do	60.89
3	6	Jas. L. Johnson	......do	19.25
2	7	Nat G. Van Doren	Field expenses	9.75
2	8	Pay roll of employees	Services, June, 1895	233.90
2	9	......do	......do	69.20
1	10	......do	......do	351.10
2	11	......do	......do	191.90
2	12	......do	......do	53.66
2	13	......do	......do	182.40
2	14	......do	......do	262.40
3	15	W. T. Walker	......do	31.50
3	19	......do	Services (job)	40.00
3	17	Don Hardy	Storage, etc	72.00
3	18	Greer Machinery Co	Buggy	49.40
5	19	T. M. Alvord	Pasturage	4.63
5	20	J. A. Lawrence	Material	52.00
5	21	R. C. McKinney	Field expenses	135.35
5	22	M. Hackett	......do	141.64
8	23	H. S. Wallace	......do	37.10
8	24	Jno. H. Renshawe	Traveling expenses	23.60
8	25	R. T. Neece	1 horse	65.00
8	26	R. H. Chapman	Field expenses	11.64
8	27	Wm. H. Herron	......do	63.05
8	28	......do	......do	48.05
8	29	Fred Stiffler	Pasturage	16.50
8	30	Fred G. Plummer	Maps	26.00
8	31	Daniel Igo	Repairs	27.00
8	32	The A. Leitz Co	......do	12.75
8	33	Thos. Lovell	Hire of team	36.50

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JULY, 1895—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
July	8	34	M. P. Henderson & Son	Pasturage	$7.50
	8	35	J. Bixley & Co	do	14.00
	8	36	J. C. Love	do	32.40
	8	37	John Arthur	Shoeing	14.50
	8	38	W. E. Doyle & Co	Meat	12.20
	8	39	California Warehouse Co	Storage	5.00
	8	40	W. H. Hyde	Material	56.00
	8	41	W. S. Rowland	Subsistence	86.25
	8	42	John A. Sims	Horse	50.00
	8	43	J. W. Thorn	Traveling expenses	13.40
	8	44	M. Hackett	do	3.18
	8	45	do	do	21.96
	8	46	J. H. Jennings	do	4.34
	8	47	R. D. Cummin	do	10.29
	8	48	W. M. Beaman	do	85.65
	8	49	Gilbert Thompson	do	6.25
	8	50	do	do	6.77
	8	51	Paul Holman	do	28.65
	8	52	Hersey Munroe	do	68 52
	8	53	Glenn S. Smith	do	31.67
	8	54	Frank Sutton	do	145.90
	8	55	E. B. Clark	do	85.75
	8	56	Robt. D Cummin	do	321.53
	8	57	W. M. Beaman	do	1.50
	8	58	do	do	105.73
	8	59	A. M. Walker	do	78.38
	8	60	W. L. Miller	do	26.65
	8	61	Jas. McCormick	do	57.75
	8	62	H. J. McLaren	Hire of team	57.00
	8	63	Chas. H. Peace	Services, June, 1895	28.00
	8	64	W S. Winters	Subsistence	76.02
	8	65	Pay roll of employees	Services, June, 1895	201.10
	10	66	E. T. Perkins, jr	Field expenses	40.10
	10	67	Frank Tweedy	do	61.45
	10	68	R. C. Hamilton	Pasturage	25.00
	10	69	A. G. Errieson	do	3.00
	11	70	Frank Sutton	Traveling expenes	12.07
	11	71	W. H. Otis	Field expenses	41.50
	11	72	L. C. Fletcher	do	101.90
	11	73	E. C. Barnard	do	97.26
	11	74	A. H. Washburn	Pasturage	10.27
	11	75	H. B. Blair	Field expenses	132.50
	11	76	T. M. Bannon	do	91.45
	11	77	R. H. Chapman	Traveling expenses	4.70
	11	78	E. M. Douglas	do	68.80
	11	79	G. E. Hyde	Field expenses	119.95
	11	80	A. E. Murlin	do	66 47
	15	81	A. B. Searle	do	4.50
	12	82	J. H. Jennings	do	102.21
	13	83	R. B. Marshall	do	118.50
	12	84	G. E. Hyde	Traveling expenses	18.80
	13	85	L. E. Fletcher	do	62.80
	13	86	James C. Malor	do	38.88
	13	87	W. H. Lovell	do	15.80
	13	88	John H. Renshawe	Boarding expenses	26.25
	13	89	J. W. Thom	Field expenses	157.88
	15	90	W. T. Griswold	do	77.76
	15	91	George O. Glavis, jr	do	3.50
	15	92	W. Lindgren	Traveling expenses	42.45

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JULY, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
July 16	93	Redick H. McKee	Field expenses	$37.37
16	94	......do	......do	27.42
15	95	Robt. T. Hill	......do	12.55
11	96	N. H. Darton	Traveling expenses	60.10
16	97	Joseph A. Taff	......do	13.90
16	98	John Quinlan	3 mules	150.00
16	99	Bradley & Goins	Repairs	15.00
16	100	R. U. Goode	Traveling expenses	58.75
16	101	Frank Tweedy	Field expenses	53.95
16	102	R. H. Chapman	......do	50.00
16	103	Walter N. Beecher	Buckboard	342.00
16	104	Fowler & Banks	1 horse	125.00
16	105	John H. Renshawe	Traveling expenses	45.80
11	106	R. H. Chapman	Field expenses	9.67
27	107	C. C. Bassett	......do	171.94
27	108	W. H. Herron	......do	77.95
27	109	J. W. Thom	......do	6.43
27	110	Robt. Muldrow	......do	97.75
27	111	Goldberg, Bowen & Lebenbaum.	Subsistence	38.53
28	112	W. S. Bayley	Traveling expenses	6.00
28	113	J. H. Wheat	......do	34.45
28	114	M. Hackett	Services, June, 1895	148.30
28	115	C. W. Hayes	Field expenses	59.84
29	116	J. H. Jennings	......do	133.72
29	117	......do	Traveling expenses	17.96
29	118	Hersey Munroe	Field expenses	40.72
29	119	H. S. Wallace	......do	63.20
29	120	Fred H. Moffett	Traveling expenses	17.92
29	121	N. H. Darton	......do	53.95
29	122	T. Nelson Dale	......do	52.97
22	123	William Kitsch	Shoeing	17.00
22	124	Roach & Co	Material	28.16
22	125	......do	Subsistence	24.65
22	126	William B. Lloyd	Material	63.55
22	127	E. M. Douglas	Traveling expenses	50.55
22	128	W. H. Otis	......do	3.30
22	129	......do	Field expenses	24.30
23	130	W. S. Post	......do	189.95
23	131	Yoder & Lewis	Subsistence	113.97
23	132	Paul Holman	Field expenses	80.60
23	133	L. C. Fletcher	......do	97.80
23	134	W. & L. E. Gurley	Sights for alidades	32.00
23	135	Chas. B. Green	Field expenses	4.15
23	136	John Macready	Supplies	46.35
25	137	H. S. Gane	Traveling expenses	46.25
25	138	Jas. L. Johnson	Field expenses	5.75
25	139	R. C. Hamilton	Pasturage	3.76
25	140	W. T. Griswold	Field expenses	50.30
25	141	Redick H. McKee	......do	84.45
25	142	C. Whitman Cross	Traveling expenses	143.10
26	143	S. S. Gannett	......do	26.70
30	144	Pay roll of employees	Services, July, 1895	344.00
30	145	......do	......do	295.60
30	146	......do	......do	388.20
30	147	......do	......do	299.00
30	148	......do	......do	425.92
30	149	......do	......do	317.90
30	150	......do	......do	299.80

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JULY, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
July 30	151	J. H. Wheat	Services, July, 1895	$91.31
30	152	Pay roll of employee	...do	201.60
30	153	...do	...do	300.60
30	154	...do	...do	251.60
30	155	...do	...do	117.90
30	156	...do	...do	169.20
30	157	...do	...do	316.33
30	158	...do	...do	210.60
30	159	E. M. Douglas	...do	210.60
30	160	Pay roll of employees	...do	338.50
30	161	...do	...do	411.90
30	162	...do	...do	362.20
30	163	T. Nelson Dale	...do	168.50
30	164	Louis M. Prindle	...do	60.00
30	165	Fred H. Moffett	...do	30.00
30	166	E. T. Perkins, jr	...do	49.15
30	167	N. H. Darton	Field expenses	62.10
30	168	Geo. L. Goulding	Traveling expenses	350.00
30	169	C. Whitman Cross	Mules	99.97
30	170	Pay roll of employees	Field expenses	368.28
30	171	...do	Services, July, 1895	440.10
30	172	N. H. Darton	...do	151.60
30	173	Pay roll of employees	...do	1,373.00
30	174	...do	...do	329.46
30	175	W. Lindgren	...do	185.30
30	176	Joseph H. Taff	...do	117.39
30	177	Edward W. Lundall	...do	19.25
30	178	W. L. Wilson	Traveling expenses	22.40
30	179	Pay roll of employees	Services, July, 1895	125.00
30	180	...do	...do	235.90
30	181	...do	...do	84.20
30	182	...do	...do	362.47
30	183	...do	...do	283.83
30	184	W. M. Beaman	...do	117.90
30	185	W. J. Lloyd	Field expenses	3.00
30	186	Frank Tweedy	...do	34.84
30	187	Pay roll of employees	Services, July, 1895	194.80
30	188	...do	...do	298.23
30	189	...do	...do	341.60
30	190	...do	...do	281.60
30	191	...do	...do	289.80
30	192	...do	...do	251.76
30	193	...do	...do	216.10
30	194	...do	...do	320.60
30	195	S. S. Gannett	Field expenses	112.25
30	196	N. S. Shaler	Services, July, 1895	200.00
30	197	J. B. Woodworth	...do	50.00
30	198	M. Hackett	...do	142.94
30	199	Pay roll of employees	...do	233.70
30	200	C. E. Bogardus	Assays	58.50
		Total		22,491.58

AUGUST, 1895.

Aug. 2	1	C. R. Van Hise	Services, July, 1895	$270.00
1	2	J. W. Thom	...do	84.20

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

AUGUST, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Aug. 6	3	Frank Leverett	Services, July, 1895	$130.00
6	4	Pay roll of employees	.....do	174.20
6	5	Wm. H. Brooks	.....do	144.00
6	6	Jos. H. Taff	Traveling expenses	144.45
6	7	T. Nelson Dale	Field expenses	5.45
6	8	M. R. Campbell	.....do	97.53
6	9	J. W. Thom	.....do	85.56
6	10	W. L. Miller	.....do	43.15
6	11	Hersey Munroe	.....do	36.05
6	12	J. H. Wheat	.....do	36.45
6	13	.....do	Traveling expenses	11.95
6	14	J. H. Jennings	.....do	6.98
6	15	C. S. Sears	Horse	45.00
6	16	R. C. McKinney	Field expenses	208.14
6	17	Jno. H. Renshawe	Boarding	36.75
10	18	R. H. Chapman	Field expenses	60.70
10	19	H. S. Wallace	.....do	45.85
10	20	Chas. A. Green	.....do	7.00
10	21	Jno. H. Renshawe	Traveling expenses	36.87
10	22	W. H. Herron	Field expenses	60.75
10	23	W. T. Griswold	.....do	102.44
10	24	California Warehouse Co	Storage	5.00
10	25	H. Zelitz	Material	6.25
10	26	M. P. Henderson & Son	Storage	4.00
10	27	Thos. Lovell	Hire of team	40.00
10	28	Frank Sutton	Traveling expenses	65.50
10	29	Robert Muldrow	.....do	5.74
10	30	Robert D. Cummin	.....do	11.50
10	31	A. M. Walker	Field expenses	82.88
10	32	D. M. Ross	Field material	85.62
10	33	T. Bascom	Traveling expenses	19.28
10	34	C. R. Van Hise	.....do	170.40
10	35	J. J. Webber	Pasturage	3.87
7	36	Geo. O. Glavis, jr	Services, July, 1895	70.80
10	37	T. M. Bannon	Field expenses	109.82
10	38	Glen S. Smith	.....do	178.63
10	39	W. M. Beaman	.....do	133.71
10	40	J. B. Woodworth	.....do	15.15
10	41	.....do	Traveling expenses	9.01
10	42	Frank Tweedy	Field expenses	54.18
10	43	Jas. McCormick	.....do	91.65
10	44	Paul Holman	.....do	64.60
10	45	Robt. D. Cummin	.....do	259.80
10	46	C. K. Leith	Services, July, 1895	53.75
10	47	Ben. K. Emerson	.....do	100.00
10	48	Pay roll of employees	.....do	507.19
10	49	J. E. Wolff	.....do	95.00
10	50	.....do	Field expenses	23.30
10	51	Chas. T. Foerste	.....do	53.55
10	52	J. Morgan Clements	.....do	9.07
10	53	H. W. Turner	.....do	24.66
10	54	T. Wayland Vaughan	.....do	12.80
10	55	.....do	.....do	7.50
10	56	Aug. F. Foerste	.....do	11.00
10	57	A. T. McConnell & Son	Subsistence	37.87
10	58	D. M. Ross	.....do	28.52
10	59	F. H. Moffett	Traveling expenses	15.22
10	60	T. Nelson Dale	.....do	53.79
12	61	W. Lindgren	.....do	31.35

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

AUGUST, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Aug. 27	62	W. Lindgren	Field expenses	$89.22
12	63	F. L. Ransome	do	6.00
12	64	Andrew C. Lawson	do	9.00
12	65	do	Traveling expenses	30.00
12	66	D. Lowry	Subsistence	22.72
12	67	Woodward & Briggs	Wagon wheels	20.00
12	68	W. S. Winters	Subsistence	49.89
12	69	Gilbert Thompson	Field expenses	34.60
12	70	Rediek H. McKee	do	44.55
12	71	W. H. Lovell	do	22.00
12	72	E. C. Barnard	do	121.16
12	73	L. C. Fletcher	do	78.83
12	74	E. T. Perkins, jr	do	25.17
12	75	S. S. Gannett	do	37.75
12	76	E. M. Douglas	do	29.35
12	77	do	Traveling expenses	94.45
12	78	R. U. Goode	do	104.05
12	79	Isaac I. Lewis	Subsistence	105.00
13	80	Frank Tweedy	Field expenses	51.84
13	81	M. Hackett	do	111.68
13	82	Nat G. Van Doren	do	26.20
13	83	L. P. Daniels	1 mule	100.00
13	84	William Ketch	Services	9.75
13	85	Roach & Co	Subsistence	58.26
13	86	C. W. Hayes	Field expenses	97.82
13	87	Robert T. Hill	do	31.35
13	88	do	do	48.95
13	89	do	Traveling expenses	15.75
13	90	G. Cramer Dry Plate Co	Dry plates	14.40
13	91	Henry B. Kummel	Services, July, 1895	58.06
16	92	H. B. Blair	Field expenses	216.97
14	93	H. W. Turner	do	64.05
14	94	C. C. Bassett	do	205.81
14	95	C. M. Hammond	Horse	100.00
14	96	E. M. Douglas	Field expenses	5.00
14	97	G. E. Hyde	do	167.90
13	98	R. B. Marshall	do	157.45
14	99	Robt. Muldrow	do	81.23
14	100	James Kelley	Services, July, 1895	7.74
16	101	W. G. Rowland	Subsistence	130.26
16	102	L. W. Estes	Pasturage	5.13
16	103	G. E. Hyde	Traveling expenses	26.75
16	104	M. Hackett	do	3.39
16	105	W. M. Beaman	do	5.17
16	106	E. B. Clark	Field expenses	95.22
16	107	A. H. Purdee	Services, July, 1895	30.00
16	108	C. D. White	Traveling expenses	53.52
16	109	do	Field expenses	47.65
16	110	Louis M. Prindle	do	.25
16	111	do	Traveling expenses	26.80
16	112	Nat G. Van Doren	Field expenses	19.87
17	113	A. E. Murlin	do	74.35
17	114	W. L. Miller	do	55.75
17	115	H. S. Wallace	do	60.20
17	116	Yoder & Lewis	Subsistence	45.10
17	117	Geo. W. Stose	Traveling expenses	15.25
17	118	John H. Renshawe	do	43.25
19	119	R. C. McKinney	Field expenses	163.15
16	120	W. S. Post	do	373.66

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

AUGUST, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Aug. 19	121	Wm. H. Herron	Field expenses	$67.65
19	122	C. Whitman Cross	do	62.62
19	123	J. H. Wheat	Traveling expenses	8.45
19	124	H. C. Lewis	Shoeing	33.50
20	125	R. B. Marshall	Field expenses	102.00
22	126	C. W. Hayes	do	75.00
22	127	A. H. Brooks	do	116.09
22	128	R. H. McKee	do	46.49
22	129	J. M. Portuondo	Services, July, 1895	27.42
22	130	L. C. Fletcher	Field expenses	62.23
18	131	W. S. Bayley	do	35.48
18	132	do	Traveling expenses	48.28
22	133	J. Morgan Clements	do	10.30
22	134	Charles Oley	Services, July, 1895	75.00
22	135	A. L. Bach	Subsistence	21.65
22	136	do	do	14.09
22	137	H. J. McLaren	Hire of team	7.00
22	138	do	do	12.00
23	139	S. S. Gannett	Field expenses	109.05
24	140	H. H. Hoover	Traveling expenses	81.53
24	141	Henry B. Kummel	do	63.74
24	142	Geo. W. Stose	do	11.00
24	143	T. Nelson Dale	do	59.37
25	144	Frank Sutton	Field expenses (July)	93.79
26	145	J. E. Spurr	do	156.38
26	146	do	Traveling expenses	10.00
26	147	T. Bascom	do	20.53
30	148	C. D. White	Services, July, 1895	134.80
31	149	R. C. McKinney	Field expenses	23.70
31	150	Jno. H. Renshawe	Services, August, 1895	210.60
31	151	Pay roll of employees	do	388.20
31	152	do	do	300.60
31	153	do	do	379.80
31	154	do	do	216.10
31	155	do	do	354.30
31	156	do	do	286.60
31	157	do	do	357.90
31	158	do	do	90.00
31	159	do	do	299.80
31	160	do	do	281.60
31	161	do	do	289.80
31	162	do	do	317.90
31	163	do	do	194.80
31	164	do	do	341.60
31	165	E. M. Douglas	do	210.60
31	166	S. S. Gannett	do	168.50
31	167	do	Traveling expenses	24.20
31	168	W. T. Griswold	Field expenses	135.89
31	169	Roach & Co	Material	20.18
31	170	A. C. Becking	do	7.95
31	171	J. W. Thom	Traveling expenses	6.35
31	172	do	do	40.40
31	173	J. H. Wheat	Services, August, 1895	101.10
31	174	Pay roll of employees	do	84.20
31	175	do	do	204.20
31	176	do	do	117.90
31	177	do	do	125.00
31	178	do	do	319.00
31	179	do	do	235.90

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

AUGUST, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Aug. 31	180	Pay roll of employees	Services, August, 1895	$304.00
31	181	Philip P. Sharples	Supplies	27.00
31	182	T. Nelson Dale	Field expenses	3.25
31	183	N. H. Darton	Traveling expenses	6.75
31	184	.....do	.....do	143.62
31	185	S. F. Emmons	.....do	105.15
31	186	Robt. T. Hill	.....do	30.50
31	187	.....do	Field expenses	46.50
31	188	J. R. Brown	Services, August, 1895	40.00
31	189	J. C. Elliott	.....do	40.00
31	190	Fred H. Moffett	.....do	30.00
31	191	T. Nelson Dale	.....do	168.50
31	192	Don Hardy	Pasturage	10.84
31	193	T. Wayland Vaughan	Services, August, 1895	84.20
31	194	N. H. Darton	.....do	151.60
31	195	Robt. T. Hill	.....do	252.70
31	196	Arthur Keith	Services, July and Aug., 1895	337.00
31	197	W. Lindgren	Services, August, 1895	185.30
31	198	Louis M. Prindle	.....do	60.00
31	199	Pay roll of employees	.....do	426.90
31	200	.....do	.....do	338.50
31	201	.....do	.....do	372.80
31	202	.....do	.....do	369.30
31	203	.....do	.....do	337.20
31	204	Geo. W. Stose	.....do	84.20
31	205	Walter H. Weep	.....do	168.50
31	206	Pay roll of employees	.....do	1,137.10
31	207	Geo. W. Glavis, jr	.....do	59.35
31	208	J. E. Spurr	Services, July and Aug., 1895	168.40
31	209	Wm. Beaman	Services, August	117.90
31	210	Pay roll of employees	.....do	201.60
31	211	.....do	.....do	369.19
31	212	.....do	.....do	251.60
31	213	.....do	.....do	328.03
31	214	.....do	.....do	320.60
31	215	J. S. Diller	.....do	202.20
31	216	W. H. Hobbs	.....do	162.00
31	217	H. S. Wallace	Field expenses	73.25
31	218	Jos. H. Perry	Traveling expenses	34.21
31	219	.....do	Services, July	48.00
31	220	Pay roll of employees	Services, August	259.80
		Total		23,681.75

SEPTEMBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 10	1	Humphreys & Co	1 horse	$35.00
9	2	Jno. H. Renshawe	Traveling expenses	76.00
9	3	.....do	Boarding	21.75
11	4	R. C. McKinney	Field expenses	94.41
11	5	H. B. Blair	.....do	168.77
11	6	E. T. Perkins, jr	.....do	78.66
9	7	J. Bixby & Co	Pasturage	14.00
11	8	Calif Warehouse Co	Storage	5.00
11	9	M. P. Henderson	.....do	6.00
11	10	C. G. Palmer	Hire of team	19.00
11	11	G. E. Hyde	Traveling expenses	16.65

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

SEPTEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 10	12	G. E. Hyde	Field expenses	$169.56
10	13	W. H. Herron	do	156.30
10	14	Frank Tweedy	do	64.85
10	15	S. S. Gannett	do	130.15
10	16	E. M. Douglas	do	83.75
10	17	do	Traveling expenses	75.15
11	18	W. S. Winters	Subsistence	22.71
9	19	Jas. Macfarland	Services, August, 1895	70.80
9	20	M. Hackett	do	134.80
4	21	Pay roll of employees	do	222.09
10	22	Nat G. Van Doren	Traveling expenses	32.97
11	23	W. H. Lovell	do	3.15
10	24	do	Field expenses	118.32
9	25	Redick H. McKee	do	35.60
9	26	do	Traveling expenses	26.25
11	27	Robt. D. Cummin	do	9.77
19	28	do	do	311.90
11	29	Robt. Muldrow	do	49.04
11	30	do	do	15.85
11	31	W. L. Miller	Field expenses	47.40
10	32	Jas. McCormick	do	91.14
10	33	Hersey Munroe	do	115.63
10	34	J. H. Wheat	do	72.80
9	35	Paul Holman	do	162.32
9	36	do	do	6.65
1	37	A. E. Murlin	do	35.30
11	38	Glen S. Smith	do	137.97
11	39	Gilbert Thompson	do	38.30
10	40	M. Hackett	do	87.65
9	41	H. C. Cowles	Services August, 1895	50.00
9	42	Henry B. Kummel	do	36.77
9	43	J. B. Woodworth	do	50.00
9	44	N. S. Shaler	do	140.00
9	45	William B. Clark	do	125.00
9	46	F. Bascom	do	14.51
9	47	Ben K. Emerson	do	95.00
9	48	C. K. Leith	do	48.00
9	49	Pay roll of employees	do	573.48
11	50	J. E. Wolff	do	75.00
11	51	James Storrs	do	60.00
11	52	A. H. Purdee	do	30.00
9	53	Pay roll of employees	do	114.90
9	54	N. H. Darton	Traveling expenses	6.00
9	55	do	do	70.24
9	56	do	Field expenses	142.24
9	57	W. Lindgren	do	278.65
11	58	H. W. Turner	do	90.33
10	59	W. C. Mendenhall	do	1.25
10	60	M. R. Campbell	do	133.68
10	61	Jos. A. Taff	do	97.55
10	62	Fred. H. Moffett	Traveling expenses	24.88
10	63	Walter H. Weed	do	86.95
10	64	D. Lowry	Field expenses	32.15
12	65	W. S. Riley	do	10.26
12	66	Metropolitan Lumber Co	do	38.36
12	67	J. B. Woodworth	do	20.90
12	68	J. E. Wolff	do	18.27
12	69	T. Wayland Vaughan	Traveling expenses	39.45
12	70	T. Nelson Dale	do	18.99

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

SEPTEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 12	71	T. Nelson Dale	Field expenses	$0.60
12	72	J. Morgan Clements	.....do	15.65
12	73	L. F. Johnson	Subsistence	82.05
12	74	L. C. Fletcher	Field expenses	48.00
12	75	W. T. Griswold	.....do	60.45
12	76	.....do	Traveling expenses	91.65
12	77	T. M. Bannon	Field expenses	122.10
12	78	Nat Tyler	.....do	9.65
12	79	Thos. Lovelle	Hire of team	38.75
12	80	E. C. Barnard	Field expenses	102.10
12	81	.....do	.....do	61.60
12	82	C. W. Hayes	.....do	60.50
13	83	Frank Lavelle	Services, August, 1895	130.00
13	84	Geo. C. Carter	.....do	20.00
13	85	Louis M. Prindle	Traveling expenses	34.41
13	86	J B. Woodworth	.....do	12.72
13	87	Henry B. Kummell	.....do	36.71
13	88	C. R. Van Hise	.....do	130.84
13	89	A. W. Walker	Field expenses	86.83
13	90	.....do	Traveling expenses	1.80
13	91	Redick H. McKee	Field expenses	31.22
13	92	M. Coleman	Services, Aug. 1-3, 1895	4.50
13	93	W. G. Rowland	Subsistence	85.13
14	94	R. B. Marshall	Field expenses	161.60
14	95	R. U. Goode	.....do	.60
14	96	.....do	Traveling expenses	114.60
14	97	R. H. Chapman	.....do	12.60
14	98	.....do	Field expenses	65.25
17	99	S. S. Gannett	.....do	120.79
17	100	L. W. Estes	Pasturage	10.50
17	101	.....do	.....do	1.80
17	102	Jeffris & Ambrose	Subsistence	62.90
17	103	R. B. Wilson	.....do	26.80
17	104	J. W. Thom	Field expenses	83.55
17	105	Geo. O. Glavis	Traveling expenses	17.75
18	106	C. D. White	Field expenses	10.24
17	107	W. C. Cochran	5 wheels	1.30
20	108	Hersey Munroe	Field expenses	61.21
20	109	Redick H. McKee	.....do	38.83
20	110	Robt. D. Cummin	.....do	113.15
20	111	.....do	.....do	30.11
20	112	O. A. Ljungstedt	Traveling expenses	22.20
20	113	W. T. Wroe	One saddle	6.75
20	114	Geo. Bland	Services, Sept. 1-8, 1895	12.00
20	115	Wm. H. Herron	Field expenses	74.65
20	116	J. Bixley & Co	Pasturage	14.00
23	117	A. E. Murlin	Field expenses	154.01
23	118	Joseph H. Perry	Traveling expenses	13.87
24	119	R. E. Dodge	.....do	29.50
23	120	Joseph H. Perry	Services, August, 1895	21.00
23	121	Frank Tweedy	Traveling expenses	21.65
24	122	.....do	Field expenses	96.48
24	123	L. C. Fletcher	.....do	64.19
24	124	Jno. H. Renshawe	Traveling expenses	65.85
24	125	W. T. Griswold	.....do	139.77
30	126	W. S. Post	Field expenses	243.81
25	127	C. Whitman Cross	.....do	107.34
25	128	Geo. O. Glavis, jr	.....do	10.60

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

SEPTEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 25	129	R. H. McKee	Field expenses	$24.10
30	130	W. Marlon Webb	Pay, August (8 days)	16.00
30	131	J. E. Spurr	Field expenses	205.75
30	132	H. S. Wallace	do	16.00
30	133	do	Traveling expenses	43.15
30	134	Basil Duke	do	41.40
30	135	Wm. H. Griffin	do	41.40
30	136	C. C. Bassett	Field expenses	139.89
30	137	Wm. H. Herron	do	64.10
30	138	R. B. Marshall	do	120.24
30	139	S. S. Gannett	do	78.85
30	140	do	Traveling expenses	7.80
30	141	A. C. Reckling	Axle grease	1.75
30	142	Eastman Kodak Co	Kodak films	10.35
30	143	T. Nelson Dale	Field expenses	32.17
30	144	do	Pay, September, 1895	163.00
30	145	W. Lindgren	do	179.40
30	146	J. S. Diller	do	195.60
30	147	Geo. W. Tower	do	60.00
30	148	Fred. H. Moffett	do	30.00
30	149	N. H. Darton	do	146 80
30	150	J. E. Spurr	do	81.60
30	151	J. B. Woodsworth	do	50.00
30	152	N. S. Shaler	do	190.00
30	153	Pay roll of employees	do	240.80
30	154	do	do	286.39
30	155	do	do	298.00
30	156	do	do	333.00
30	157	do	do	364.40
30	158	do	do	1,704.00
30	159	do	do	312.00
30	160	do	do	222.60
30	161	do	do	222.80
30	162	do	do	246.80
30	163	do	do	258.67
30	164	do	do	297.00
30	165	do	do	196.80
30	166	do	do	114.20
30	167	do	do	359.47
30	168	do	do	81.60
30	169	W. M. Beaman	do	114.20
30	170	M. Hackett	do	130.40
30	171	E. M. Douglas	do	203.80
30	172	A. L. Estes	do	40.00
30	173	Langley Hall, jr	do	50.00
30	174	S. S. Gannett	do	163.00
30	175	Pay roll of employees	do	276.80
30	176	do	do	342.00
30	177	do	do	306.80
30	178	do	do	281.80
30	179	do	do	212.80
30	180	do	do	190.40
30	181	do	do	349.20
30	182	do	do	314.20
30	183	do	do	285.40
30	184	do	do	311.62
30	185	do	do	295.40
30	186	Jno. H. Renshawe	Services, September, 1895	203.80

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

SEPTEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Sept. 30	187	Pay roll of employees	Pay, September, 1895	$255.40
30	188	....do	....do	370.40
30	189	....do	....do	370.60
30	190	....do	....do	288.80
		Total		21,725.06

OCTOBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Oct. 4	1	J. H. Wheat	Traveling expenses	$30.75
3	2	Pay roll of employees	Services, September, 1895	293.80
3	3	....do	....do	228.20
5	4	Joseph Macfarland	....do	68.40
1	5	C. D. White	....do	130.40
5	6	Ben. K. Emerson	....do	90.00
5	7	Frank Leverett	....do	125.00
5	8	A. H. Purdee	....do	30.00
5	9	Henry C. Cowles	....do	50.00
5	10	C. R. Van Hise	....do	250.00
5	11	Chas. Oley	....do	32.50
5	12	C. K. Leith	....do	31.25
5	13	J. Morgan Clements	....do	88.00
5	14	Pay roll of employees	....do	276.99
4	15	W. Lindgren	Traveling expenses	15.25
4	16	....do	Field expenses	42.60
9	17	Paul Holman	....do	156.75
9	18	A. M. Walker	Traveling expenses	1.80
9	19	J. Morgan Clements	Field expenses	45.66
9	20	....do	Traveling expenses	3.07
9	21	....do	....do	42.67
9	22	T. Nelson Dale	Field expenses	1.26
9	23	....do	Traveling expenses	16.89
9	24	Fred. H. Moffett	....do	26.03
9	25	S. F. Emmons	....do	147.79
9	26	....do	....do	64.00
9	27	W. C. Mendenhall	....do	2.50
9	28	....do	....do	12.75
9	29	A. H. Brooks	....do	16.75
9	30	Joseph A. Taff	....do	17.00
9	31	O. A. Ljungstedt	....do	16.15
10	32	C. R. Van Hise	....do	152.47
10	33	....do	Field expenses	7.79
10	34	Louis M. Prindle	Traveling expenses	39.05
10	35	....do	Services, September, 1895	38.00
10	36	Sagola Lumber Co	Subsistence	19.77
10	37	Metropolitan Lumber Co	....do	11.17
10	38	Jno. Starck	Trays	7.50
10	39	S. E. Alston	Hire of transportation	9.50
10	40	W. S. Winters	Subsistence	38.75
10	41	Morrison & Williams	....do	61.20
10	42	J. W. Thom	Field expenses	92.65
10	43	J. H. Wheat	....do	144.28
10	44	Jas. McCormick	....do	90.96
10	45	Gilbert Thompson	....do	38.08
10	46	Hersey Munroe	....do	38.90

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

OCTOBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Oct. 10	47	Robert Muldrow	Traveling expenses	$2.70
10	48	Frank Tweedy	Field expenses	68.15
10	49	E. Knight	Hire of horse	22.50
10	50	W. G. Griswold	Subsistence	92.30
10	51	A. G. Ericson	Pasturage	3.00
10	52	J. Bixby & Co	......do	14.00
10	53	L. W. Estes	......do	10.50
10	54	California Warehouse Co	Storage	5.00
10	55	M. P. Henderson & Son	......do	4.00
12	56	L. C. Fletcher	Field expenses	49.95
12	57	Robert Muldrow	......do	96.25
12	58	A. E. Murlin	......do	97.44
12	59	......do	......do	66.80
12	60	A. M. Walker	......do	82.64
11	61	Nat G. Van Doren	......do	4.50
12	62	R. U. Goode	......do	124.47
12	63	H. W. Turner	......do	52.65
12	64	W. S. Bayley	......do	13.25
12	65	......do	Traveling expenses	45.70
12	66	M. Hackett	......do	2.28
12	67	......do	Field expenses	101.75
12	68	E. M. Douglas	......do	31.60
12	69	......do	Traveling expenses	170.75
12	70	T. M. Bannon	Field expenses	136.08
15	71	R. C. McKinney	......do	152.68
15	72	Nat Tyler, jr	......do	9.75
15	73	W. S. Post	......do	221.40
15	74	R. H. Chapman	......do	64.46
15	75	......do	......do	16.00
15	76	Thos. Lovell	Hire of transportation	33.25
15	77	W. H. Lovell	Field expenses	104.51
15	78	A. H. Brooks	......do	1.75
15	79	Joseph A. Taff	......do	91.64
15	80	Wm. B. Clark	Pay, September, 1895	120.00
15	81	E. B. Clark	Field expenses	51.28
15	82	E. C. Barnard	......do	79.16
15	83	......do	......do	79.44
15	84	H. B. Blair	......do	226.80
15	85	C. C. Bassett	......do	135.38
16	86	W. S. Wallace	......do	20.85
16	87	......do	......do	19.50
16	88	Jno. H. Renshawe	Traveling expenses	35.50
16	89	George Graham	Pay, Oct. 1-6, 1895	6.77
16	90	R. B. Marshall	Field expenses	112.11
16	91	G. E. Hyde	Traveling expenses	21.50
16	92	......do	Field expenses	113.28
16	93	S. S. Gannett	......do	45.85
16	94	W. G. Griswold	......do	33.75
16	95	......do	Traveling expenses	60.90
16	96	E. J. Owenhouse	Subsistence	32.25
16	97	J. E. Wolff	Traveling expenses	11.30
16	98	......do	Field expenses	37.71
16	99	......do	Services, September, 1895	110.00
16	100	Wm. H. Hobbs	......do	150.00
16	101	H. W. Turner	Field expenses	66.70
16	102	W. Lindgren	......do	165.01
16	103	C. Whitman Cross	......do	104.56
16	104	Fred. H. Moffett	Traveling expenses	10.33
16	105	T. Nelson Dale	......do	16.10

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

OCTOBER, 1895—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Oct.	17	106	C. W. Hayes	Field expenses	$88.19
	17	107	Walter H. Weed	Services, September, 1895	163.00
	17	108	Geo. C. Carter	do	15.00
	17	109	W. L. Miller	Field expenses	13.00
	17	110	Redick H. McKee	do	57.00
	17	111	do	do	35.00
	18	112	C. W. Goodlove	do	2.00
	18	113	do	do	12.50
	18	114	do	Services, September, 1891	41.58
	18	115	Chas. B. Green	Services, Aug. and Sept., '95	165.80
	21	116	E. T. Perkins	Field expenses	162.93
	21	117	W. H. Herron	do	63.25
	21	118	do	do	68.40
	21	119	Jas. L. Johnson	do	5.80
	21	120	I. M. Long	Services	1.50
	21	121	A. V. Douglas	do	4.68
	21	122	H. C. Hoover	Traveling expenses	29.50
	21	123	do	Field expenses	10.25
	21	124	J. E. Spurr	do	223.10
	21	125	do	Traveling expenses	5.00
	24	126	E. T. Perkins, jr	Field expenses	69.50
	24	127	Hersey Munroe	do	79.76
	24	128	Jno. H. Renshawe	do	20.25
	24	129	Jos. Lacross	do	26.25
	24	130	do	do	26.25
	24	131	do	do	26.25
	31	132	E. M. Douglas	Pay, October, 1895	210.60
	31	133	C. W. Goodlove	do	75.80
	31	134	Pay roll of employees	do	379.80
	31	135	do	do	303.20
	31	136	do	do	357.90
	31	137	do	do	259.80
	31	138	do	do	281.60
	31	139	do	do	311.60
	31	140	Frank Tweedy	Field expenses	47.84
	31	141	Pay roll of employees	Services, October, 1895	286.60
	31	142	do	do	325.60
	31	143	do	do	299.80
	31	144	do	do	317.90
	31	145	do	do	226.10
	31	146	do	do	295.60
	31	147	do	do	201.60
	31	148	do	do	311.66
	31	149	do	do	228.70
	31	150	do	do	235.90
	31	151	do	do	195.17
	31	152	do	do	160.00
	31	153	J. S. Clemmer	Services, September, 1895	11.66
	31	154	Fred H. Moffett	Services, October, 1895	9.68
	31	155	H. W. Turner	do	168.50
	31	156	F. L. Ransome	do	75.00
	31	157	Nelson H. Darton	do	151.60
	31	158	W. Lindgren	do	185.30
	31	159	T. Nelson Dale	do	168.50
	31	160	do	do	2.72
	31	161	Pay roll of employees	do	2,267.50
	31	162	W. S. Winters	Subsistence	6.55
	31	163	S. S. Gannett	Field expenses	118.10
	31	164	do	Traveling expenses	67.70

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

OCTOBER, 1895—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Oct.	31	165	Harold B. Goodrich	Traveling expenses	$4.75
	31	166	....do	....do	25.75
	31	167	J. B. Woodsworth	Pay, October, 1895	50.00
	31	168	Pay roll of employees	....do	245.96
	31	169	....do	....do	289.80
	31	170	....do	....do	349.00
	31	171	R. C. McKinney	....do	134.80
	31	172	Jno. H. Renshawe	....do	210.60
	31	173	S. S. Gannett	....do	168.50
	31	174	R. H. Chapman	....do	134.80
	31	175	Jno. G. Chapman	....do	37.03
	31	176	Hans C. Biering	....do	37.03
	31	177	Wm. H. Griffin	Field expenses	19.00
	31	178	....do	....do	19.50
	31	179	Basil Duke	....do	19.00
	31	180	....do	....do	19.50
	31	181	Pay roll of employees	Pay, October, 1895	216.10
	31	182	....do	....do	369.00
	31	183	Robert Muldrow	Traveling expenses	63.50
	31	184	G. W. Tower	....do	5.00
	31	185	C. Whitman Cross	Services, October, 1895	202.20
	31	186	Wm. Beaman	Pay, October, 1895	117.90
	31	187	Frank Sutton	....do	151.60
	31	188	Langley Hall	....do	30.65
	31	189	A. L. Estes	....do	23.22
	31	190	J. E. Spurr	....do	84.20
	31	191	Nat Tyler, jr	....do	75.80
	31	192	....do	Traveling expenses	36.50
	31	193	R. C. McKinney	....do	36.50
	31	194	M. P. Henderson & Son	Storage	4.00
	31	195	Rediek H. McKee	Field expenses	51.01
	31	196	Jos. Macfarland	Traveling expenses	32.60
	31	197	Pay roll of employees	Services, October, 1895	117.90
	31	198	J. S. Diller	....do	202.20
	31	199	C. D. White	....do	134.80
	31	200	N. S. Shaler	....do	160.00
	31	201	W. S. Bayley	Traveling expenses	69.74
	31	202	M. R. Campbell	Field expenses	149.45
			Total		21,040.52

NOVEMBER, 1895.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Nov.	2	1	Nat Tyler, jr	Field expenses	$39.35
	6	2	L. C. Fletcher	....do	94.60
	2	3	Joseph Macfarland	....do	6.50
	4	4	J. H. Wheat	....do	138.78
	6	5	R. H. Chapman	....do	103.62
	6	6	....do	Traveling expenses	29.50
	2	7	Nat G. Van Doren	Field expenses	42.12
	6	8	....do	Traveling expenses	8.72
	2	9	M. Hackett	Services, October, 1895	134.80
	2	10	S. Ward Loper	Services, July 15–Sept. 9,'95	96.00
	2	11	Pay roll of employees	Services, October, 1895	170.60
	2	12	G. W. Tower	....do	60.00
	6	13	Ben. K. Emerson	....do	75.00
	6	14	C. D. White	Field expenses	19.82

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

NOVEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Nov. 6	15	C. D. White	Traveling expenses	$30.00
6	16	M. P. Campbell	Services, October, 1895	151.60
8	17	Wm. B. Clark	.....do	90.00
8	18	Frank Leverett	.....do	135.00
8	19	W. S. Bayley	.....do	75.00
8	20	C. R. Van Hise	.....do	200.00
8	21	H. Leydler	.....do	92.50
8	22	J. Morgan Clements	.....do	108.00
17	23	Geo. O. Glavis	Services, Oct. 1–18, 1895	41.09
8	24	Jno. H. Renshawe	Field expenses	17.25
12	25	R. C. McKinney	.....do	136.04
12	26	C. W. Goodlove	.....do	4.00
12	27	T. M. Bannon	.....do	176.11
12	28	H. S. Wallace	.....do	43.50
12	29	.....do	.....do	16.50
12	30	C. C. Bassett	.....do	196.58
12	31	Joseph Lacross	Hire of team	22.75
12	32	.....do	.....do	22.75
12	33	.....do	.....do	22.75
12	34	S. E. Cook	Pay, October, 1895	40.00
12	35	W. T. Walker	.....do	45.00
12	36	L. C. Fletcher	Field expenses	31.25
12	37	E. T. Perkins, jr	.....do	66.25
12	38	W. T. Griswold	.....do	84.00
12	39	.....do	Traveling expenses	98.40
12	40	R. U. Goode	.....do	155.15
12	41	California Warehouse Co	Storage	5.00
12	42	L. W. Estes	Pasturage	10.50
12	43	J. Bixley & Co	.....do	14.00
12	44	W. T. Reid	Services	24.00
12	45	E. Knight	Hire of horse	23.25
12	46	A. C. Reckling	Supplies	2.10
12	47	W. S. Winters	Subsistence	20.60
12	48	W. H. Joren	Traveling expenses	4.77
12	49	M. Hackett	.....do	3.84
12	50	Hersey Munroe	Field expenses	18.50
12	51	Gilbert Thompson	.....do	40.75
12	52	W. H. Lovell	.....do	128.76
12	53	Jas. McCormick	.....do	17.75
12	54	A. M. Walker	.....do	107.22
12	55	S. Ward Loper	Traveling expenses	53.27
12	56	G. H. Storrs	Pay, Oct. 1–Nov. 6, 1895	53.33
12	57	Peter Johnson	.....do	51.00
12	58	C. K. Leith	Pay, October, 1895	37.50
12	59	Paul Halman	Field expenses	172.15
13	60	Wm. H. Griffin	.....do	46.50
13	61	.....do	.....do	18.50
13	62	Frank Sutton	.....do	43.56
13	63	A. E. Murlin	.....do	79.26
13	64	.....do	.....do	29.58
13	65	Merrill Hackett	.....do	107.21
13	66	Redick H. McKee	.....do	17.68
13	67	.....do	Traveling expenses	35.25
13	68	W. L. Miller	.....do	28.10
13	69	C. W. Hayes	.....do	14.30
13	70	.....do	.....do	27.25
13	71	W. Lindgren	Field expenses	201.20
13	72	W. H. Turner	.....do	89.70
13	73	Samuel Weidman	Pay, October, 1895	29.03

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

NOVEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Nov. 13	74	John H. Starek	Trays	$3.75
13	75	T. Nelson Dale	Field expenses	6.17
13	76	C. R. Van Hise	.....do	3.55
13	77	Chas. A. Coryell	Hire of team	14.00
13	78	Robt. Muldrow	Field expenses	142.37
13	79	L. H. Barnett	Services, Nov. 1–7, 1895	11.60
13	80	T. F. Higgenbothan	Services, Oct. 26–31, 1895	5.00
13	81	W. G. Rowland	Subsistence	117.84
13	82	H. E. Wallace	Pasturage	11.47
13	83	L. W. Estes	.....do	6.00
13	84	M. A. Johnson	.....do	18.00
13	85	G. E. Hyde	Traveling expenses	29.60
13	86	.....do	Field expenses	161.70
16	87	Wm. H. Herron	.....do	58.70
15	88	J. E. Spurr	.....do	238.32
18	89	Jno. H. Renshawe	Traveling expenses	150.79
18	90	T. M. Bannon	.....do	9.45
18	91	.....do	Field expenses	88.19
18	92	E. C. Barnard	.....do	82.10
18	93	.....do	.....do	124.70
18	94	R. B. Marshall	.....do	191.53
18	95	Redick H. McKee	.....do	37.52
18	96	W. L. Miller	.....do	4.75
18	97	J. W. Thom	.....do	130.85
18	98	R. Guy Foster	Pay, Nov. 1–4, 1895	6.66
18	99	J. H. Wheat	Traveling expenses	24.30
18	100	H. C. Hoover	Field expenses	26.30
18	101	H. W. Turner	Traveling expenses	10.60
18	102	.....do	.....do	90.85
18	103	F. C. Schrader	Services, Oct. 29–31, 1895	5.00
18	104	J. E. Spurr	Field expenses	50.00
21	105	Robt. T. Hill	Traveling expenses	90.95
21	106	Geo. C. Carter	Services, October, 1895	60.00
21	107	Basil Duke	Field expenses	43.50
21	108	.....do	.....do	18.50
21	109	.....do	Traveling expenses	36.00
21	110	Jno. H. Renshawe	.....do	111.65
21	111	A. B. Searle	.....do	36.28
21	112	Wm. H. Griffin	.....do	36.00
21	113	Frank Tweedy	.....do	35.10
21	114	.....do	Field expenses	62.04
21	115	.....do	.....do	54.90
21	116	W. T. Griswold	.....do	111.37
21	117	Hersey Munroe	.....do	61.51
18	118	William Johnson	Services, November, 1895	15.16
22	119	N. H. Darton	Traveling expenses	35.91
22	120	.....do	Field expenses	38.50
25	121	E. T. Perkins, jr	.....do	98.20
25	122	W. J. Lloyd	.....do	4.00
25	123	Wm. H. Herron	.....do	58.20
25	124	.....do	.....do	65.45
25	125	S. S. Gannett	.....do	90.15
25	126	.....do	Traveling expenses	55.30
25	127	Robt. D. Cummin	Field expenses	89.36
26	128	C. Whitman Cross	Traveling expenses	100.55
26	129	E. C. E. Lord	.....do	93.50
30	130	Pay roll of employees	Pay, November, 1895	212.80
30	131	.....do	.....do	255.40

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

NOVEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Nov. 30	132	R. H. Chapman	Pay, November, 1895	$130.40
30	133	J. L. Windham	....do	21.00
30	134	Pay roll of employees	....do	220.40
30	135	....do	....do	251.60
30	136	....do	....do	187.60
30	137	....do	....do	212.00
30	138	Glen S. Smith	....do	60.00
30	139	J. H. Wheat	....do	97.80
30	140	Pay roll of employees	....do	235.40
30	141	....do	....do	314.20
30	142	Pay roll of employees	....do	382.00
30	143	E. T. Perkins, jr	....do	130.40
30	144	S. S. Gannett	....do	163.00
30	145	Duncan Hannegan	....do	81.60
30	146	W. Lindgren	....do	179.40
30	147	G. W. Tower	....do	60.00
30	148	J. E. Spurr	....do	81.60
30	149	T. Nelson Dale	....do	163.00
30	150	Pay roll of employees	....do	63.66
30	151	F. L. Ransome	Traveling expenses	43.63
30	152	....do	Services, November, 1895	75.00
30	153	Duncan Hannegan	Traveling expenses	39.30
30	154	Arthur Keith	Services, Oct. and Nov., 1895	331.50
30	155	Pay roll of employees	Services, November, 1895	3,117.80
30	156	....do	....do	309.80
30	157	E. M. Douglas	Traveling expenses	204.25
30	158	....do	Field expenses	47.30
30	159	....do	....do	47.75
30	160	H. B. Blair	....do	171.84
30	161	E. C. Barnard	Services, November, 1895	146.80
30	162	W. H. Otis	....do	75.00
30	163	J. G. Hefty	....do	34.50
30	164	W. V. Hardy	....do	29.33
30	165	H. G. Heisler	....do	45.00
30	166	N. F. Drake	....do	50.00
30	167	L. C. Fletcher	....do	146.80
30	168	....do	....do	98.53
30	169	Duncan Hannegan	....do	6.75
30	170	....do	....do	9.50
30	171	W. Hyndman	Storage	5.00
30	172	J. M. Whitman, jr	Pay, Nov. 1–28, 1895	46.67
30	173	Pay roll of employees	....do	203.20
30	174	....do	....do	81.60
30	175	Jas. McCormick	Field expenses	57.10
30	176	J. H. Wheat	....do	52.67
30	177	M. R. Campbell	Traveling expenses	41.10
30	178	N. S. Shaler	Pay, November, 1895	150.00
30	179	J. B. Woodsworth	Services, November, 1895	50.00
30	180	Jno. R. Walsh	....do	114.20
30	181	Jas. S. Stone	Pasturage	15.10
30	182	C. Whitman Cross	Field expenses	120.51
30	183	....do	....do	20.50
30	184	W. S. Post	Traveling expenses	78.55
		Total		17,613.23

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

DECEMBER, 1895.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Dec. 5	1	H. B. Blair	Traveling expenses	$46.50
4	2	.....do	Field expenses	115.04
5	3	Paul Holman	.....do	152.90
5	4	C. C. Bassett	.....do	183.30
5	5	L. C. Fletcher	.....do	75.79
5	6	W. S. Post	.....do	251.30
4	7	E. C. Barnard	.....do	152.85
4	8	E. T. Perkins, jr	Traveling expenses	65.65
5	9	J. Bixley & Co	Pasturage	14.00
5	10	M. P. Henderson	Storage	4.00
5	11	L. W. Estes	Forage	8.17
5	12	Rice & Gill	Meat	14.95
5	13	W. T. Walker	Forage and storage	50.00
5	14	W. S. Wilson	Subsistence	16.10
5	15	Robt. Muldrow	Traveling expenses	12.00
5	16	Albert Pike	.....do	16.00
5	17	.....do	Field expenses	7.25
5	18	Hersey Munroe	.....do	46.90
5	19	.....do	Traveling expenses	17.50
5	20	S. S. Gannett	Field expenses	60.14
5	21	Charles E. Peet	Traveling expenses	64.29
5	22	J. E. Spurr	Field expenses	134.74
5	23	C. R. Van Hise	.....do	6.50
5	24	.....do	Services, November, 1895	200.00
5	25	J. Morgan Clements	.....do	100.00
5	26	Ernest Blackburn	.....do	58.00
5	27	Ben. K. Emerson	.....do	70.00
5	28	Wm. B. Clark	.....do	65.00
5	29	C. K. Leith	.....do	39.25
5	30	L. M. Haskins	Services, Oct. and Nov., 1895	100.00
5	31	M. A. Johnson	Pasturage	18.00
5	32	M. R. Campbell	Traveling expenses	3.55
5	33	.....do	.....do	19.55
5	34	E. C. Barnard	.....do	118.50
5	35	L. C. Fletcher	.....do	109.75
5	36	G. E. Hyde	.....do	36.45
10	37	G. E. Hyde	Field expenses	96.35
10	38	W. S. Post	.....do	116.55
10	39	W. G. Rowland	Subsistence	129.65
10	40	E. Knight	Hire of horse	22.50
10	41	California Warehouse Co	Storage	5.00
10	42	Jno. Hunton	Forage	17.25
10	43	W. H. Lovell	Traveling expenses	5.25
10	44	Gilbert Thompson	Field expenses	55.20
10	45	W. B. Kelley	Storage	5.00
10	46	S. E. Alston	Hire of transportation	15.00
10	47	N. H. Darton	Traveling expenses	43.80
10	48	W. S. Bayley	Pay, November, 1895	75.00
10	49	F. C. Schrader	.....do	12.00
10	50	Frank Leverett	.....do	130.00
10	51	W. T. Griswold	Field expenses	85.70
10	52	.....do	Traveling expenses	98.55
11	53	A. M. Walker	.....do	2.25
11	54	.....do	Field expenses	79.40
11	55	J. W. Thom	.....do	87.80
11	56	Robt. Muldrow	.....do	138.42
11	57	Henry Stewart Gane	Traveling expenses	141.30
12	58	Jas. McCormick	.....do	19.38
12	59	W. H. Lovell	Field expenses	133.05
12	60	A. B. Searle	.....do	70.14

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

DECEMBER, 1895—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Dec. 12	61	Gilbert Thompson	Field expenses	$6.25
12	62	....do	Traveling expenses	14.40
12	63	W. H. Otis	....do	10.55
16	64	Geo. H. Eldridge	....do	65.90
16	65	....do	....do	103.24
16	66	....do	....do	64.92
12	67	Robt. D. Cummin	....do	18.75
16	68	M. Hackett	....do	3.05
16	69	....do	....do	27.50
16	70	....do	....do	88.13
16	71	A. E. Murlin	Field expenses	57.30
16	72	....do	....do	16.85
16	73	Wm. H. Herron	....do	37.05
16	74	R. B. Marshall	....do	186.06
16	75	R. H. Chapman	....do	65.70
16	76	....do	Traveling expenses	35.75
16	77	....do	....do	28.25
19	78	Glenn S. Smith	....do	16.77
19	79	Oscar Jones	....do	1.92
18	80	A. E. Murlin	....do	33.92
18	81	....do	Field expenses	11.92
19	82	J. E. Spurr	Traveling expenses	164.50
19	83	B. F. Rice, jr	Services, Dec. 1–15, 1895	24.19
19	84	Willis Storrs	Services, Dec. 1–13, 1895	16.77
20	85	Hans Biering	Pasturage	45.40
21	86	W. C. Mendenhall	Traveling expenses	35.85
21	87	Paul Holman	....do	40.95
23	88	C. C. Bassett	....do	24.25
23	89	Louis F. Garrard, Jr	Pay, November, 1895	73.40
26	90	Oscar Jones	Pay, Dec. 1–7, 1895	11.29
26	91	Jno. H. Carlock	....do	9.03
26	92	....do	Traveling expenses	2.42
28	93	A. M. Walker	....do	6.85
28	94	S. S. Gannett	Field expenses	174.10
28	95	....do	Traveling expenses	23.25
28	96	A. M. Walker	Field expenses	58.05
31	97	J. Z. Aken	Forage	16.77
31	98	N. B. Dunn	....do	68.25
31	99	James Marshall	Storage	3.00
31	100	E. W. Watkins	....do	4.00
31	101	M. Hackett	Field expenses	5.66
31	102	Pay roll of employees	Pay, December, 1895	159.48
31	103	....do	....do	216.10
31	104	....do	....do	219.00
31	105	T. Nelson Dale	....do	168.50
31	106	W. Lindgren	....do	185.30
31	107	J. B. Woodsworth	....do	50.00
31	108	Pay roll of employees	....do	3,534.67
31	109	G. W. Tower	....do	60.00
31	110	H. C. Hunt	Care of stock	35.10
31	111	Clarence Ritter	Forage	45.60
31	112	William O. Campbell	Pay, July 1–Dec. 31, 1895	24.00
31	113	Louis F. Garrard, jr	Traveling expenses	53.50
31	114	C. C. Bassett	Field expenses	99.29
31	115	Robert Muldrow	Pay, December, 1895	117.90
31	116	Glenn S. Smith	....do	60.00
31	117	Pay roll of employees	....do	85.14
31	118	....do	....do	174.81
		Total		11,028.99

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JANUARY, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Jan. 2	1	Jno. Tannehill	Storage	$8.75
2	2	D. W. White	Forage	15.83
2	3	C. A. Gunderson	Pay, December, 1895	35.00
2	4	J. L. Windham	do	35.00
2	5	D. L. Fairchild	do	75.00
2	6	W. H. Otis	do	75.00
2	7	W. T. Turner	do	60.00
2	8	J. G. Pratt	Storage	4.50
2	9	M. P. Henderson & Son	do	4.00
2	10	S. W. Barnes	Storage and forage	60.94
2	11	H. S. Pritchett	Services	50.00
2	12	W. G. Lewis, jr	Pay, December, 1895	35.42
2	13	J. P. Street & Co	Storage	1.61
2	14	T. Nelson Dale	Field expenses	.50
2	15	C. W. Hayes	do	3.23
2	16	do	do	35.70
2	17	do	do	44.40
2	18	do	Traveling expenses	32.95
2	19	do	do	24.75
2	20	C. R. Van Hise	Pay, December, 1895	220 00
2	21	J. Morgan Clements	do	92.00
2	22	W. S. Bayley	do	60.00
2	23	C. K. Leith	do	44.25
2	24	E. P. Maurer	do	35.25
2	25	Samuel Wiedman	do	23.25
2	26	L. J. Keng	do	10.60
4	27	N. S. Shaler	do	180.00
4	28	Arthur Keith	Field expenses	10.40
4	29	J. W. Thom	do	173.62
4	30	Thos. Hoover	Storage	35.00
4	31	Fred Stifler	Pasturage	33.60
4	32	E. P. Kaye	do	13.54
4	33	do	do	34.66
4	34	G. E. Hyde	Field expenses	70.15
4	35	do	Traveling expenses	137.00
4	36	Wm. H. Herron	do	52.25
4	37	do	Field expenses	60.05
4	38	W. J. Lloyd	Traveling expenses	52.25
4	39	do	do	6.00
4	40	W. T. Walker	Storage and forage	50.00
6	41	C. R. Van Hise	Field expenses	6.70
6	42	do	Traveling expenses	32.42
6	43	H. W. Turner	Field expenses	21.85
6	44	Frank Leverett	Pay, December, 1895	125.00
6	45	Arthur Keith	Traveling expenses	91.15
6	46	do	do	131.61
6	47	do	do	13.95
6	48	R. B. Marshall	do	113.75
7	49	Ernest Blackburn	Services, December, 1895	28.00
7	50	Ben K. Emerson	do	65.00
9	51	C. W. Hayes	Field expenses	66.20
6	52	do	do	22.50
9	53	J. E. Spurr	do	68.37
9	54	Harold B. Goodrich	do	18.35
9	55	do	do	11.00
9	56	do	Traveling expenses	8.75
9	57	do	do	33.05
9	58	M. A. Johnson	Foraging	42.00
9	59	J. Bixby & Co	do	4.50

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JANUARY, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Jan. 9	60	John Johnson	Foraging	$22.50
9	61	L. W. Estes	do	27.30
9	62	California Warehouse Co.	Storage	2.50
9	63	Humphries & Co	Supplies	27.00
9	64	do	Foraging	34.15
9	65	N. H. Darton	Traveling expenses	18.32
9	66	W. H. Lovell	do	7.75
9	67	do	Field expenses	105.00
9	68	A. B. Searle	do	131.94
9	69	Robert Muldrow	do	59.97
10	70	do	Traveling expenses	32.95
11	71	Jas. L. Johnson	do	24.90
10	72	do	Field expenses	6.00
14	73	Chas. E. Peet	Traveling expenses	68.65
16	74	Wm. Wilkinson	Foraging	77.75
16	75	Anna J. Grugan	do	9.60
16	76	Samuel F. Alston	Foraging, etc	11.03
17	77	Aug. F. Foerste	Services, July, 1895	75.00
17	78	do	Traveling expenses	15.70
17	79	do	do	27.65
21	80	Harold B. Goodrich	Field expenses	2.50
21	81	do	do	4.00
21	82	Joseph H. Perry	Pay, Sept. 1–Dec. 31, 1895	33.00
21	83	T. M. Alvord	Pasturage	22.06
21	84	W. Sandercock	Storage	2.33
22	85	A. G. Ericsson	Pasturage	3.00
22	86	Wm. Hyndman	Storage	5.00
22	87	D. L. Fairchild	Traveling expenses	30.75
22	88	J. B. Woodsworth	do	36.35
24	89	J. H. Jennings	do	44.68
24	90	A. B. Searle	do	31.43
24	91	do	Field expenses	56.38
24	92	J. M. Whitman, jr	Pay, Jan. 8–17, 1896	16.13
24	93	W. J. Houston, jr	Pay, Dec. 1–17, 1895	27.37
24	94	Henry J. Kummell	Pay, January, 1896	18.00
25	95	W. Lindgren	Traveling expenses	34.25
28	96	W. H. Lovell	do	35.43
28	97	do	Field expenses	41.23
28	98	W. J. Houston, jr	Traveling expenses	16.07
28	99	J. W. Thom	do	6.60
28	100	do	do	5.56
28	101	do	do	41.15
28	102	R. B. Marshall	Field expenses	155.87
28	103	W. T. Turner	Pay, Jan. 1–19, 1896	36.77
28	104	W. H. Otis	do	45.97
28	105	Orvil Dodge	Storage	1.00
28	106	T. M. Bannon	Field expenses	133.27
28	107	do	do	110.24
28	108	do	do	75.34
28	109	do	Traveling expenses	61.05
29	110	W. J. Lloyd	Field expenses	112.98
30	111	Pay roll of employees	Pay, January, 1896	160.00
27	112	W. J. Lloyd	do	85.20
30	113	G. W. Tower	do	60.00
30	114	Pay roll of employees	do	3,833.60
30	115	do	do	221.50
30	116	W. Lindgren	Traveling expenses	15.45
30	117	do	do	3.00

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JANUARY, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Jan. 31	118	R. B. Marshall	Field expenses	$60.22
31	119	W. J. Lloyd	do	17.00
31	120	T. Nelson Dale	do	.80
31	121	do	Pay, January, 1896	148.35
		Total		9,545.60

FEBRUARY, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Feb. 4	1	W. T. Walker	Forage, etc	$50.00
4	2	John Hunton	do	22.50
4	3	Wm. Hyndman	Storage	5.00
4	4	Saml. F. Alston	Forage and storage	38.00
4	5	Thomas Hoover	do	35.00
4	6	N. B. Dunn	Forage	45.00
4	7	M. A. Johnson	do	42.00
4	8	Nichols & Fischer	Pasturage	18.25
4	9	N. S. Shaler	Pay, January, 1896	160.00
4	10	C. R. Van Hise	do	270.00
4	11	L. J. Keng	do	12.20
4	12	C. L. Leith	do	40.37
4	13	J. Morgan Clements	do	52.00
4	14	W. S. Bayley	do	80.00
4	15	Ben. K. Emerson	do	60.00
4	16	J. C. Merriam	do	8.00
4	17	W. S. T. Smith	do	12.00
4	18	F. L. Ransome	do	6.00
4	19	J. B. Woodworth	do	50.00
4	20	do	Field expenses	7.75
4	21	Andrew C. Lawson	do	29.25
4	22	do	Pay, January, 1896	65.00
4	23	W. J. Lloyd	Field expenses	21.10
10	24	do	Traveling expenses	27.50
10	25	Arthur Stiles	do	15.45
10	26	R. L. Salisbury	do	48.50
10	27	Chas. E. Peet	do	60.46
10	28	do	do	30.28
10	29	C. M. Mollahan	Pasturage	103.75
10	30	C. J. Brodard	do	75.60
12	31	Fred Stifler	do	18.00
12	32	L. W. Estes	do	15.00
12	33	J. Bixby & Co	do	4.50
12	34	Mrs. L. C. Brown	do	8.12
12	35	M. P. Henderson & Son	Storage	4.00
12	36	Carlifornia Warehouse Co	do	2.50
13	37	R. B. Marshall	Field expenses	11.35
13	38	F. C. Schrader	Pay, January, 1896	32.00
17	39	William B. Clark	Pay, Dec. 1-Feb. 15, 1896	75.00
24	40	N. F. Drake	Pay, Feb. 10-15, 1896	18.00
29	41	G. W. Tower	Pay, February, 1896	60.00
29	42	T. Nelson Dale	do	137.36
29	43	Pay roll of employees	do	3,586.80
		Total		5,463.59

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

MARCH, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Mar. 2	1	Pay roll of employees	Services, February, 1895	$239.60
2	2	W. T. Walker	Care of stock	50.00
2	3	T. M. Alvord	do	8.00
2	4	Anna J. Green	do	8.00
2	5	M. A. Johnson	do	42.00
2	6	J. B. Woodsworth	Services, February, 1896	50.00
5	7	N. S. Shaler	do	150.00
5	8	Ben. K. Emerson	do	60.00
5	9	J. Morgan Clements	do	32.00
5	10	L. J. Keng	do	55.40
5	11	C. K. Leith	do	35.50
5	12	C. R. Van Hise	do	250.00
5	13	do	Traveling expenses	31.54
5	14	do	Field expenses	10.50
5	15	Samuel T. Alston	Forage and storage	38.00
5	16	Thomas Hoover	do	35.00
5	17	W. B. Dunn	Forage	45.00
7	18	W. J. Lloyd	Field expenses	81.50
9	19	Clarence Ritter	Forage	48.00
9	20	William Hyndman	Storage	5.00
11	21	T. M. Alvord	Forage	8.00
11	22	Mrs. L. C. Brown	do	8.00
11	23	J. Bixby & Co	do	4.50
11	24	W. S. Bayley	Pay, February, 1896	65.00
12	25	California Warehouse Co	Storage	2.50
14	26	L. W. Estes	Forage	15.00
14	27	Fred Stifler	do	18.00
14	28	M. P. Henderson & Son	Storage	4.00
14	29	C. M. Harlan	Forage	76.30
16	30	Anna J. Grugan	do	8.00
17	31	Walter H. Weed	Traveling expenses	89.50
20	32	N. H. Darton	do	13.95
31	33	Pay roll of employees	Pay, March, 1896	3,834.10
31	34	T. Nelson Dale	do	170.30
31	35	G. W. Tower	do	60.00
31	36	Pay roll of employees	do	177.77
31	37	J. B. Woodsworth	do	50.00
		Total		5,829.96

APRIL, 1896.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
Apr. 1	1	C. R. Van Hise	Traveling expenses	$8.62
1	2	C. M. Harlan	Foraging stock	37.50
1	3	H. C. Biering	do	49.20
1	4	S. W. Barnes	do	115.50
1	5	E. P. Kaye	do	60.00
1	6	do	do	60.00
2	7	W. B. Kelly	do	15.00
2	8	E. W. Watkins	Storage	6.00
2	9	J. B. Street & Co	do	6.00
2	10	James Manahale	do	6.00
2	11	N. B. Dunn	Foraging stock	45.00
2	12	J. Z. Akin	do	60.00
2	13	Thomas Hoover	do	35.00
2	14	Saml. F. Alston	do	38.00
2	15	W. J. Lloyd	Field expenses	89.54

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

APRIL, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
Apr.	3	16	D. W. White	Foraging stock	$28.50
	3	17	H. C. Hunt	do	14.59
	3	18	W. T. Walker	do	50.00
	3	19	Jno Hunton	do	22.50
	3	20	Wm. Hyndman	Storage	5.00
	3	21	M. A. Johnson	Foraging	42.00
	3	22	N. S. Shaler	Pay, March, 1896	200.00
	3	23	C. R. Van Hise	do	260.00
	3	24	J. Morgan Clements	do	44.00
	3	25	C. K. Leith	do	40.75
	6	26	W. S. Bayley	do	60.00
	6	27	C. W. Hayes	Cash paid for pasturage	94.50
	11	28	T. Nelson Dale	Traveling expenses	48.52
	11	29	Andrew C. Lawson	Field expenses	6.00
	11	30	do	Services, March, 1896	30.00
	11	31	B. K. Emerson	do	41.67
	11	32	California Warehouse Co	Storage	2.50
	1	33	J. Bixby & Co.	Foraging stock	4.50
	11	34	Mrs. L. C. Brown	do	8.00
	11	35	Orvil Dodge	Storage	3.00
	11	36	L. W. Estes	Foraging stock	15.00
	11	37	John Tannehill	Storage	7.50
	11	38	W. J. Lloyd	Traveling expenses	90.75
	13	39	Arthur Stiles	do	20.80
	13	40	Anna J. Grugan	Foraging stock	8.00
	14	41	C. J. Bradford	do	126.00
	17	42	M. P. Henderson & Son	Storage	4.00
	17	43	C. W. Goodlove	Traveling expenses	14.50
	18	44	do	do	6.25
	18	45	Arthur Keith	do	16.80
	18	46	A. Buford	do	9.55
	18	47	Geo. H. Eldridge	do	18.75
	18	48	C. R. Van Hise	Field expenses	1.70
	18	49	T. B. Byrd	do	28.38
	22	50	T. M. Alvord	Foraging stock	8.00
	23	51	T. C. Chamberlin	Pay, July 1, 1895–Apr. 1, 1896	110.00
	23	52	M. R. Campbell	Traveling expenses	35.90
	24	53	W. C. Mendenhall	do	36.10
	24	54	W. Landercock	Storage	2.62
	25	55	Wm. Wilkerson	Pasturage	63.00
	27	56	A. E. Murlin	Field expenses	4.40
	28	57	N. H. Darton	Traveling expenses	22.10
	30	58	T. Nelson Dale	Field expenses	.50
	30	59	do	Pay, April, 1896	154.00
	30	60	G. W. Tower	do	60.00
	30	61	Pay roll of employees	do	3,890.25
			Total		6,402.24

MAY, 1896.

May	1	1	W. T. Walker	Care of stock	$50.00
	1	2	John Hunton	do	22.50
	1	3	J. B. Woodworth	Pay, April, 1896	50.00
	4	4	N. S. Shaler	do	200.00
	5	5	A. Buford	do	54.00

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

MAY, 1896—Continued.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
May	5	6	E. R. Maurer	Pay, April, 1896	$18.00
	5	7	Leonard S. Smith	do	15.00
	5	8	C. K. Leith	do	46.50
	5	9	J. Morgan Clements	do	104.00
	5	10	C. R. Van Hise	do	200.00
	5	11	do	Field expenses	21.77
	5	12	M. A. Johnson	Care of stock	18.00
	5	13	Fred Stifler	do	18.00
	5	14	do	do	18.00
	7	15	F. M. Alvord	Storage	8.00
	7	16	California Warehouse Co	do	2.50
	7	17	M. P. Henderson & Son	do	4.00
	7	18	Saml. F. Alston	Care of stock	38.00
	7	19	N. B. Dunn	do	45.00
	7	20	Thomas Hoover	do	35.00
	7	21	J. E. Wolff	Pay, April, 1896	45.00
	7	22	do	Field expenses	3.65
	11	23	W. S. Bayley	Pay, April, 1896	25.00
	11	24	Ovil Baines	do	5.00
	11	25	Joseph Williams	do	25.00
	11	26	J. T. Roberts & Son	Hire of team	45.00
	11	27	A. M. Walker	Traveling expenses	11.29
	11	28	do	Field expenses	42.75
	11	29	M. Hackett	do	48.95
	11	30	do	Traveling expenses	2.09
	11	31	J. Bixby & Co	Pasturage	4.50
	11	32	L. W. Estes	do	15.00
	11	33	Mrs. L. C. Brown	do	8.00
	11	34	Wm. Hyndman	Storage	5.00
	12	35	J. E. Wolff	Traveling expenses	31.38
	12	36	J. H. Jennings	do	7.30
	14	37	Anna J. Grugan	Pasturage	8.00
	16	38	J. G. Pratt	Storage	7.50
	16	39	Geo. H. Eldridge	Field expenses	21.15
	16	40	T. B. Byrd	Supplies	17.98
	18	41	A. H. Brooks	Traveling expenses	19.00
	20	42	Robert Muldrow	do	9.55
	20	43	do	do	3.90
	20	44	J. E. Macfarland	do	17.92
	20	45	do	Field expenses	28.23
	20	46	N. H. Darton	do	31.08
	20	47	do	Traveling expenses	22.14
	22	48	Clarence Ritter	Pasturage	48.00
	22	49	N. H. Darton	Field expenses	21.50
	27	50	T. Nelson Dale	do	2.00
	27	51	do	Pay, May, 1896	140.00
	27	52	Geo. H. Eldridge	Field expenses	4.02
	27	53	do	do	35.72
	28	54	do	Traveling expenses	6.40
	31	55	G. W. Tower	Pay, May, 1896	60.00
	31	56	Pay roll of employees	do	3,569.30
	31	57	N. H. Darton	do	153.40
	31	58	J. E. Macfarland	do	71.60
			Total		5,591.57

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JUNE, 1896.

Date of payment.		No. of voucher.	To whom paid.	For what paid.	Amount.
June	1	1	J. E. Macfarland	Traveling expenses	$22.29
	1	2	.....do	Field expenses	27.50
	1	3	N. H. Darton	.....do	16.75
	1	4	.....do	Traveling expenses	48.62
	1	5	W. C. Mendenhall	.....do	6.75
	1	6	A. H. Brooks	.....do	14.80
	1	7	J. B. Woodworth	.....do	2.60
	1	8	.....do	.....do	5.25
	1	9	.....do	Pay, May, 1896	50.00
	1	10	N. S. Shaler	.....do	200.00
	1	11	Frank Leverett	.....do	130.00
	1	12	R. N. Boyd	.....do	13.50
	1	13	Orvil Barnes	.....do	10.06
	1	14	A. Buford	.....do	60.00
	1	15	T. J. Roberts & Son	Hire of team	93.00
	1	16	A. M. Walker	Field expenses	26.00
	1	17	.....do	Traveling expenses	1.85
	1	18	Wm. O. Campbell	Storage	16.00
	2	19	M. Hackett	Field expenses	40.95
	2	20	.....do	Traveling expenses	4.16
	5	21	W. T. Walker	Forage and storage	50.00
	5	22	Thomas Hoover	.....do	35.00
	5	23	N. B. Dunn	.....do	20.00
	5	24	C. R. Van Hise	Pay, May, 1896	240.00
	5	25	J. Morgan Clements	.....do	100.00
	5	26	C. K. Leith	.....do	52.80
	9	27	Wm. H. Hobbs	.....do	24.00
	9	28	Andrew C. Lawson	.....do	70.00
	9	29	.....do	Field expenses	20.00
	9	30	C. M. Mollohan	Pasturage	143.00
	9	31	A. H. Brooks	Field expenses	32.20
	9	32	Fred Stifler	Pasturage	18.05
	9	33	L. W. Estes	.....do	15.00
	9	34	T. M. Alvord	.....do	8.00
	9	35	Wm. Hyndman	Storage	5.00
	9	36	M. P. Henderson & Son	.....do	4.00
	9	37	California Warehouse Co	.....do	2.50
	10	38	Mrs. L. C. Brown	Pasturage	8.00
	10	39	J. Bixby & Co	.....do	4.50
	11	40	M. R. Campbell	Traveling expenses	17.30
	11	41	W. S. Bayley	Pay, May, 1896	85.00
	12	42	Philip Miller & Co	Supplies	16.09
	12	43	A. M. Walker	Traveling expenses	1.01
	12	44	.....do	Field expenses	13.75
	15	45	W. S. Mendenhall	Traveling expenses	17.35
	15	46	M. A. Johnson	Boarding stock	18.00
	16	47	John Hunton	.....do	22.50
	16	48	N. H. Darton	Field expenses	42.13
	19	49	J. E. Macfarland	.....do	14.50
	19	50	Geo. H. Eldridge	.....do	7.76
	19	51	D. W. White	Forage and storage	26.34
	19	52	Thomas Hoover	Care of stock	8.50
	19	53	W. B. Kelly	.....do	12.50
	20	54	Norton L. Taylor	Tracing map	6.00
	22	55	Anna J. Grugan	Pasturage	8.00
	23	56	Aug. F. Foerste	Field expenses	12.15
	23	57	.....do	Pay, Aug. 1-8, 1895	19.35
	24	58	C. R. Van Hise	Traveling expenses	9.37

Abstract of disbursements made by C. D. Davis, special disbursing agent, United States Geological Survey, etc.—Continued.

GENERAL EXPENSES OF THE GEOLOGICAL SURVEY, 1895 AND 1896—Continued.

JUNE, 1896—Continued.

Date of payment.	No. of voucher.	To whom paid.	For what paid.	Amount.
June 24	59	J. E. Wolff	Traveling expenses	$33.88
24	60	Bailey Willis	do	12.82
24	61	G. K. Gilbert	do	40.73
24	62	do	do	52.95
26	63	S. F. Alston	Pasturage	61.00
30	64	N. H. Darton	Pay, June, 1896	148.30
30	65	J. E. Macfarland	do	69.20
30	66	T. Nelson Dale	do	133.00
30	67	Pay roll of employees	do	190.56
30	68	do	do	343.30
30	69	do	do	265.40
30	70	do	do	437.36
30	71	do	do	137.40
30	72	W. L. Miller	do	82.40
30	73	G. W. Tower	Pay, June 1-25, 1896	50.00
30	74	do	Pay, June 26-30, 1896	13.74
30	75	Pay roll of employees	Pay, June, 1896	2,695.55
30	76	do	do	181.30
30	77	J. E. Spurr	do	131.90
30	78	Geo. Otis Smith	Pay, June 29-30, 1896	5.49
30	79	Joseph H. Taff	Pay, June, 1896	115.40
		Total		7,201.41

Amount expended as per abstracts	$645,205.50
Bonded railroad accounts settled at United States Treasury	1,870.10
Total expenditures	647,075.60

NECROLOGY.

GEORGE HUNTINGTON WILLIAMS.

George Huntington Williams was born in Utica, N. Y., on January 28, 1856, and died there on July 12, 1894. He remained in his native city, at the home of his parents, Robert S. and Abigail Williams, during boyhood and youth, following the course of the public schools and graduating at the head of his class from the Utica Free Academy. In 1874 he entered Amherst College, and graduated in the class of 1878. These college years determined his future career in great degree, for the interest in geology awakened in the student under the instruction of Prof. B. K. Emerson never failed. After some months of post-graduate work in geology at Amherst and a short experience in teaching at his old home, he went to Germany in the summer of 1879 to pursue his studies in his chosen science.

The greater part of the first year was spent at the University of Göttingen, and the two succeeding ones at Heidelberg. The studies of these three years gave special direction to the energies and interest of the young American. At Göttingen he worked in mineralogy under Prof. C. Klein, and in Heidelberg his attention was chiefly given to the comparatively new science of petrography, under the eminent master, Prof. H. Rosenbusch. He received the degree of Doctor of Philosophy from the University of Heidelberg in December, 1882, his thesis being a petrographical study of a district in the Black Forest. Thus equipped in a new line of research, he returned to this country, and was not long in finding a fruitful field of labor.

Owing partly to the fact that he was not naturally of strong physique, Dr. Williams did not seek to enter the service of the Geological Survey, for which he was otherwise so well fitted, but turned to university life as a more congenial field for his many-sided abilities. He found Johns Hopkins University just about to establish a geological department, and in March, 1883, as "fellow by courtesy," he began alone to build up what has become, largely through his efforts, one of the principal geological departments of the country. In 1884 he became a member of the academic staff of the university as "associate;" in 1885 he rose to the grade of associate professor, and in 1892 he was made professor of inorganic geology.

As a university professor, Dr. Williams exhibited many talents. He quickly made his course of instruction in petrography the most thorough in the country, but with keen perception of present opportunities and a rare power of creating new ones he soon developed his department beyond a specialty and made it strong in many ways. His strength was also given to the general advancement of the university, in which he became an influential leader.

Dr. Williams's power as a teacher was shown by the success with which he imparted his own enthusiastic love for his science to those who came under his instruction. To this success the large number of his students now found in professional life is ample testimony. Nor was this power confined to the class room, for his popular lectures and written articles have done much to make his specialty and the broader science to which it belongs better known to the general public.

But the university work, varied as it was, did not keep the student in a new branch of science from the field of original research, and it is this phase of his life work which must be more especially considered at this time. Almost at once he entered into the examination of the geology of the vicinity of Baltimore, and soon found rich material for investigation in the ancient igneous rocks and the metamorphic forms derived from them. After various preliminary notices, he published, in 1886, a bulletin of the Geological Survey (No. 28) On the Gabbros and Associated Hornblende Rocks occurring in the Neighborhood of Baltimore, Maryland. This was the first in a series of investigations of the older rocks of Maryland, in which he enlisted the services of his advanced students. Gradually the scope of the studies themselves broadened, as the area examined increased, until Dr. Williams had become quite thoroughly acquainted with the pre-Cambrian eruptive and metamorphic rocks of Maryland, and had followed the interesting problems suggested by them into many other parts of the eastern United States. Among the publications presenting these general results may be mentioned the one on the Distribution of Ancient Volcanic Rocks along the Eastern Border of North America (Journal of Geology, 1894), and that on The General Relations of the Granitic Rocks in the Middle Atlantic Piedmont Plateau, published after the author's death in the Fifteenth Annual Report of the Survey.

In the expression of these discoveries upon maps, Dr. Willims had long been working in connection with this Survey, and several atlas sheets in which he was responsible for portions of the work are now in process of publication. Much more work had been planned. A geological map of the vicinity of Baltimore, of which he was the editor and chief contributor, has been issued by the Johns Hopkins University, and a geological map of the State of Maryland, containing many new features, accompanied the book entitled Maryland, prepared by G. H. Williams and W. B. Clark, and published by the State board of managers for the World's Fair Commission.

The geographical range of Dr. Williams's investigations was great. In 1884 and 1885 he spent some months in the Marquette and Menominee iron districts of Michigan, engaged in a study of the metamorphic greenstones of the region and the problems of their origin. The results of this investigation are contained in a bulletin of the Survey (No. 62). A series of remarkable igneous rocks on the Hudson attracted his attention, and as the Cortlandt series these rocks are now well known to petrographers. From all sides material came to him for investigation, and hence his petrographical writings treat of rocks from Brazil, Alaska, Canada, and many parts of the United States.

While Dr. Williams's contributions to geology and petrology are of very great value, it was evident to those most closely associated with him that they were but preparatory to more important work. At the time of his death he was formulating a discussion of metamorphic rocks with regard to their origin and classification. Could he have accomplished this it would have added greatly to our knowledge of these important and as yet little understood rocks.

Dr. Williams never lost his interest in purely mineralogical investigation, as numerous descriptive papers testify, and he was especially expert and thorough in crystallographic work. His course of instruction in crystallography led him to the publication of a text-book which is extensively used in colleges.

Years of personal acquaintance and association had led the Director to place a high estimate on the skill and judgment of Dr. Williams, and a few days prior to his fatal illness a conference was held in the office of the Geological Survey in reference to assigning to him general charge of the investigation of the crystalline rocks of the northern Appalachians. The interval of nearly two years that has elapsed since his death has served to impress upon his former official associates the greatness of the loss to science in general and to the Geological Survey in particular.

DEPARTMENT OF THE INTERIOR, UNITED STATES GEOLOGICAL SURVEY.

PAPERS ACCOMPANYING THE ANNUAL REPORT

OF THE

DIRECTOR OF THE U. S. GEOLOGICAL SURVEY

FOR THE

FISCAL YEAR ENDING JUNE 30, 1896.

MAGNETIC DECLINATION IN THE UNITED STATES.

BY

HENRY GANNETT.

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MAGNETIC DECLINATION IN THE UNITED STATES.

By Henry Gannett.

INTRODUCTION.

The following compilation and discussion of magnetic declination within the United States is designed to meet the needs of those who have occasion to use the needle in surveying, or who have to deal with surveys which have been run by needle in past times.

In those parts of the country in which declination data are abundant I have compiled such data to the extent that seemed necessary, selecting only the most accurate. In those parts of the country where declination data are scanty I have obtained all such data as could be found.

All data obtainable for the discussion of the secular variation in declination have been obtained and used, and the results are presented in the form of tables, showing the approximate reduction to a selected epoch—namely, the year 1900—at each tenth year prior to that time for the period during which it may be required. Finally, the declination data have been reduced to this epoch, 1900, and are presented in the table by counties, cities, and towns, which is believed to be the most convenient form in which the data can be presented for the use of surveyors.

SOURCES OF DATA.

The observations for magnetic declination or variation of the compass which have been collected and are discussed in this paper are derived from a variety of sources and present great variation in point of accuracy and trustworthiness.

United States Coast and Geodetic Survey.—For many years the United States Coast and Geodetic Survey has been engaged not only in the compilation and discussion of these observations, but in observing, and thus obtaining data. Its stations, though few in number, have been occupied by the most skilled observers and equipped with the finest instruments for this work, and the results, barring certain unavoidable errors, are thoroughly trustworthy. Its stations are not confined to the neighborhood of the coast, but are scattered over the interior of the country. The results, together with a large amount of compiled data, have been published from time to time in the reports of the United States Coast and Geodetic Survey, the latest publications being in the annual reports of 1888 and 1889.

The United States Lake Survey, during the progress of its work upon the Northern and Northwestern lakes, made many magnetic stations in that region, and the results are of the first class. These results are published in Professional Papers, Corps of Engineers, Report on Primary Triangulation, 1882.

General Land Office.—From the commencement of the work of subdividing public lands under the General Land Office one of the requirements of the contractors for this survey has been that the magnetic declination be observed in every township. This requirement has, in general, been conformed to, and the result is that in every township thus far subdivided in the United States, numbering some 60,000, the magnetic declination is on record in the archives of the General Land Office. In every State excepting the original thirteen, with those formed from them, and with the addition of Texas, the magnetic declination has been observed very fully, although not always very accurately, and is a matter of record. In many, perhaps half of the cases, the declination is given upon the plats of the townships, and is thus in easily accessible form. In other cases, where it is omitted from the township plats, it is to be found in the notes accompanying the plats, although here it is not so easy of reference. Furthermore, the Land Office requires that in the survey of all standard and exterior lines the declination be observed, and the records of the declination observed in connection with these lines are to be found upon the plats of those lines or in the notes accompanying them. The declinations observed upon the standard and exterior lines, being obtained with special instruments, are, as a rule, of greater accuracy than those observed in connection with the subdivision of townships.

These surveys of the General Land Office have been made at various dates, commencing in the latter part of the last century, when work was begun in Ohio, and ranging thenceforward to the present time, the work at present being mainly in the mountain and desert regions of the far West and in Indian Territory. In point of accuracy these observations differ greatly. As a rule those of earlier dates are not of as great accuracy as those of recent date. In the early years of the work it appears to have been the practice, after obtaining the declination from observation, to use it over considerable areas. The quality of the determinations appears to be rather a function of the personality of the surveyor than of any other matter. Taken as a whole, however, this vast body of observations, which has been practically untouched heretofore, is of the greatest value in studying the distribution of magnetic declination over the country.

I have not attempted to make a complete collection of this material. The amount is too vast to make it worth while. I have, however, collected all the observations which appear upon the plats of exteriors and standard lines, supplementing them wherever needed by observations made in connection with the subdivision of townships. Altogether, I have abstracted from the plats of the General Land Office nearly 20,000 observations, and these form perhaps nine-tenths of the material herewith presented. The character of these observations will be discussed in greater detail in connection with the discussion of the results in the several States.

Many State boundaries, especially in the West, have been run by contractors under the General Land Office, and in the course of their surveys many observations for magnetic declination have been made. These, which are commonly of good quality, have been utilized.

In the State of Missouri, and to a small extent in the adjoining States of Illinois, Iowa, and Kansas, Professor Nipher observed, in the years 1878 to 1884, at several hundred stations. His results were published in the Transactions of the St. Louis Academy of Sciences. These results, which are of excellent quality, have been adopted; and as they cover the State of Missouri quite completely, and as the observations for declination by the General Land Office in that State have every appearance of being poor in quality, I have contented myself with using those of Professor Nipher only.

New York State Survey.—The State Survey of New York, under Mr. James T. Gardiner, between the years 1876 and 1884, carried on a primary triangulation of parts of the State, and in connection therewith took numerous observations for declination upon its stations. These were published in the final report of that survey. The Geological Survey of New York also has published the results from a few stations, and the Adirondack and State Land Survey, under Mr. Verplanck Colvin, whose field of operations lies mainly in the Adirondacks, observed at a few stations. The results are published in the reports of that organization.

National Academy of Sciences.—Between 1870 and 1880 the National Academy of Sciences made a small appropriation for observations of magnetic declination, which work was intrusted to the United States Coast and Geodetic Survey, and the results have been published by that organization. They are designated in the accompanying list by the initials N. A. S.

Wheeler, Hayden, and Powell surveys.—The Western surveys carried on between 1869 and 1878, known as the Wheeler, Hayden, and Powell surveys, took numerous observations for magnetic declination in connection with the map work which they were executing. These observations were commonly made with small compasses, and the results are not very reliable. Those of the Hayden survey were furnished in manuscript to the United States Coast and Geodetic Survey, by whom they were published. Those of the Wheeler survey were published in the annual reports of that organization.

Army exploring expeditions.—Other expeditions which have traversed the West have furnished a few scattering observations. Among these may be mentioned the expeditions of Capt. W. H. Emory, Lieut. J. C. Ives, Capt. W. A. Raynolds, and Capt. W. S. Stanton.

Boundary surveys.—In connection with the survey of the northern boundary of the United States from the Lake of the Woods to the Rocky Mountains many declinations were observed, and these are presumably of excellent quality. They were published in the report of that survey.

New Jersey Geological Survey.—The State of New Jersey, through the agency of its Geological Survey, has made a full collection of data for magnetic declination, which is published in Volume I of the final report of that survey.

Pennsylvania.—The State of Pennsylvania, through its Secretary of Internal Affairs, has collected a large amount of data of this kind from county surveyors throughout the State, which is published in the reports of the secretary, and specially in Part I of the report for 1887.

Maine Geological Survey.—This survey has made a few determinations in the State.

The United States Corps of Engineers has, aside from the work of the Lake survey, made numerous determinations of declination in various parts of the country, mainly in connection with its river and harbor work, and these are to be found in scattering form in the annual reports of the Chief of Engineers.

Other sources.—Besides the sources above given, there may be mentioned Locke's Report on Mineral Lands, 1839–40, and Stone's Magnetic Variations, 1878, both of which contain data.

With the exception of the results by the General Land Office, most of the sources of data above enumerated have been consulted and the data compiled by Mr. C. A. Schott in the papers published by him under the United States Coast and Geodetic Survey. To this work I shall have frequent occasion to refer hereafter as being the only comprehensive work on magnetic declination in the United States at present. From these sources Mr. Schott has compiled the results from some 2,500 stations in the country. His data are relatively abundant in the older Eastern States, while in the Mississippi Valley and in the West they are very scanty. It is difficult to understand how he could have overlooked the vast mine of information on this subject which is contained in the General Land Office, which would have supplemented his material in the regions where it is most needed.

In the fall of 1895 I sent a circular to all county surveyors in the country, requesting their cooperation to the extent of furnishing me with any recent determinations of declination which they had made or could obtain, together with any information which would bear upon the question of the secular change in declination. To this circular I have received some 850 replies, giving in each case the declination, commonly in the current year, and information concerning secular variation, consisting of series of observations or their experience in the rerunning of lines. This information will be set forth hereafter.

From all these sources I have compiled the declination at about 22,000 stations in the United States. The results, reduced to the year 1900, are presented in the final table of this volume, arranged by States and counties. In the Land Office States several stations have been obtained from the public-land surveys in nearly every county, and the declination in the few remaining counties has been estimated from that in the adjoining counties. In the older States, where there are no observations by the General Land Office, stations are much fewer and the number of counties in which it was necessary to estimate the declination much greater.

VARIATIONS IN MAGNETIC DECLINATION.

The magnetic declination is subject to several changes. During the day it changes from 10′ to 15′, being highest in the morning at 7 or 8 o'clock and least in the early afternoon, returning to its maximum position at 8 or 9 in the evening. This is called the "diurnal change." There is also a monthly change of small magnitude, so inconsiderable as to be of no practical importance. There is also a slight oscillation at different times of the year, but this is also of trifling magnitude. There is a fourth regular change, known as the "secular variation," which is progressive for a long term of years. Its normal amount ranges in different parts of the country from 3′ to 4′ per year, but in certain portions of the country, as will be shown hereafter, the change is at present quite different in amount, being subject to certain laws which, so far as their operation is concerned, will be explained more at length.

The magnetic needle is subject also to what may be called "magnetic storms," which at times influence it greatly, causing temporary changes of declination of great magnitude without any apparent reason therefor.

Of the changes which are of magnitude, the secular variation alone can commonly be provided for and corrected. As a rule we do not know the hour of the day at which the observations were taken, and we can make no provisions for the effects of magnetic storms. If we add to the effect of these the imperfections of instruments, for which, of course, no correction can be applied in the case of compiled observations, and the unknown effect of local attraction, and of the ignorance and carelessness of observers, it may be easily understood that we are dealing with a somewhat uncertain mass of data, and should be prepared for discrepancies of considerable magnitude in the observations.

THE SECULAR VARIATION.

The magnetic declination is zero on a line passing through the lower peninsula of Michigan, central Ohio, eastern Kentucky and Tennessee, and western North Carolina, finally passing down to the Atlantic through South Carolina, near the course of the Savannah River. East of this line the declination is to the westward, and increases in amount eastward. West of this line the declination is eastward, and increases in amount westward. The largest west declination is in eastern Maine, where it amounts to approximately 22°. The largest east declination is in northwest Washington, where it reaches 23°.

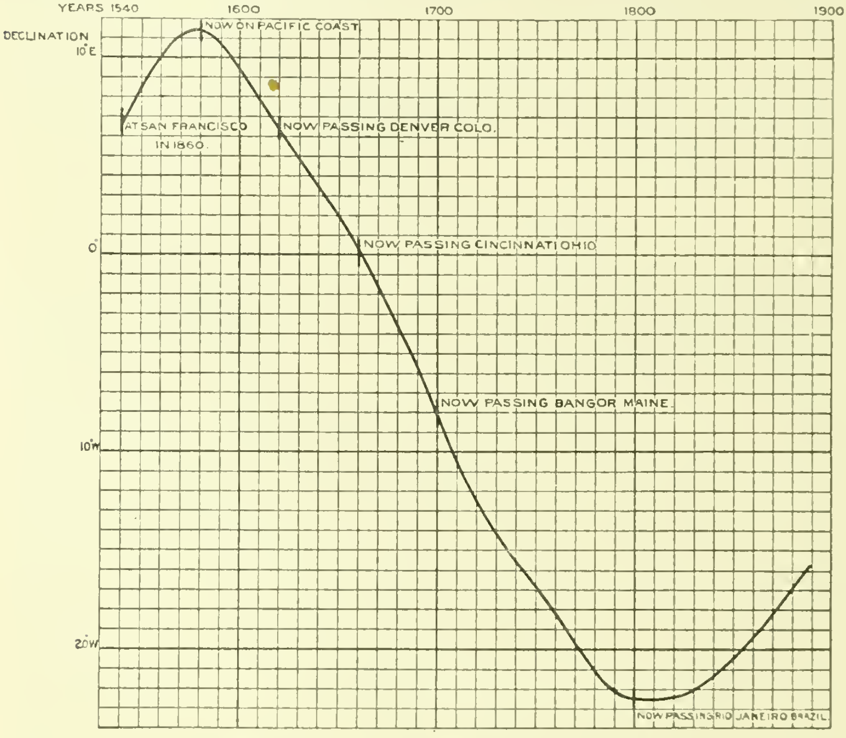


Fig. 1.—Diagram of magnetic declination at Paris, France.

The secular variation is an annual change in the declination amounting, on the average, in the northern part of the country to 4′ per year, and diminishing southward, until in Florida and Texas it is 3′ annually. This annual change increases west declination and decreases east declination. It is probably almost uniform at present in the eastern and central parts of the country except for this diminution southward, but passing westward toward the Pacific Coast it diminishes rapidly, and upon the coast of northern California, Oregon, and Washington it is practically zero at about this time, i. e., the declination is practically at a standstill, while in recent years east declination has been increasing in this region.

The secular variation, regarded as a function of time, has the form of a curve, somewhat similar to a hyperbola, being nearly a straight line, curving therefrom to a summit, falling off with a similar curve, and developing again into nearly a straight line on the other side of the summit. The typical form of the curve is seen in the diagram, fig. 1, showing the curve at Paris, which is taken from "Schott's Secular Variation in the United States," Report United States Coast and Geodetic Survey, 1888. As will be seen from the diagram, the summit of the curve passed the observatory at Paris in the year 1580. In about one hundred and seventy-five years this summit appeared upon this side of the Atlantic, and passed Eastport, Me., at about 1750 or 1760. It is now, 1896, passing over San Francisco, and in 1900 will be upon the one hundred and twenty-fifth meridian in the Pacific Ocean. Its progress across the Atlantic and the United States has apparently been at a nearly uniform rate of about 10° of longitude in twenty years. As nearly as can be made out from the obervations, the crest of the wave has moved nearly on a meridian, being found in practically the same longitude at the same time in all latitudes in the United States and at points in South America.

The above statements regarding its movement, which were first suggested as a working hypothesis, have been subjected to tests furnished by the following series of observations and have been found to hold good as nearly as it is possible to determine. Under this hypothesis the summit of the curve occupied the following positions in longitude in the years named:

Year.	Longitude	Year.	Longitude.
	°		°
1790	70	1850	100
1800	75	1860	105
1810	80	1870	110
1820	85	1880	115
1830	90	1890	120
1840	95	1900	125

The form of the curve within twenty or twenty-five years on either side of its summit, where the secular variation changes, is a matter of interest. Mr. Schott determines this by forming an equation for each series of observations, deducing therefrom corrections which he applies to other stations within its neighborhood, thus assuming as many different curves as there are stations at which he has series of observations.

The observations at Paris and London show that a second change in the secular variation passed these places about the beginning of the present century. This second change is now passing over Rio Janeiro, Brazil, longitude 43° W., as is shown by a series of observations published by Schott in the Annual Report of the United States Coast and Geodetic Survey for 1888.

The observations in New England show in recent years a slight reduction in the rate of secular variation, which may foreshadow the approach of this change. If this be the case, however, it is moving at a more rapid rate than its predecessor, which required about one hundred and seventy years to pass from Paris to Eastport, Me. It is more probable, therefore, that the reduction in the rate of secular variation in New England, which is noticeable in the table following, is due to some local disturbance of the secular change rather than to this general movement.

Before proceeding to analyze the character of the secular variation further it will be desirable to give in extenso all data which are available for studying its form and its location at different times.

These data are of varied character, consisting of—

(1) Series of observations taken at the same station. Most of these have been taken from the collection compiled and published by Mr. Schott in the bulletin of the Coast and Geodetic Survey above quoted, with a few contributed by county surveyors. In certain cases these series furnished by Mr. Schott's compilation have been extended by the addition of more recent observations.

(2) Data furnished by county surveyors, consisting in the results of experience derived from rerunning old lines at different dates. Assuming that the lines as originally run were upon the declinations as stated, the departures from these declinations, which are required for rerunning them at present, are the changes in declination, and the result is correct, regardless of the question whether the original declinations upon which the lines were run were correct declinations or not.

(3) In cases where the areas of the counties in Land Office States are not large, and where the county seat is near the center of the county, the mean of the declinations observed by the surveyors of the General Land Office at the time the county was subdivided is given, in comparison with the declination in 1895 or 1896 as furnished by the county surveyors at the county seats.

DATA FOR DETERMINATION OF SECULAR VARIATION.

MAINE.

BANGOR.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1805	11 15	1844	14 29
1837	14 04	1857	15 20
1840	13 22	1879	16 29

Data for determination of secular variation—Continued.

MAINE—Continued.

EASTPORT.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1833	14 30	1864	18 04
1857	15 21	1865	18 06
1860	17 57	1873	18 56
1861	17 59	1879	19 08
1862	18 01	1887	18 35
1863	18 02	1895	*a* 19 42

a County surveyor.

PORTLAND.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1833	10 00	1861	12 44
1845	11 28	1865	12 42
1851	11 41	1866	12 43
1859	11 20	1873	12 43
1863	12 23	1887	13 51

NEW HAMPSHIRE.

CHESTERFIELD.

The following series from 1808 to 1847 were observed by Mr. Wild, formerly surveyor of Cheshire County, and were furnished in manuscript by Mr. Samuel Wadsworth, the present surveyor:

Year.	Declination.	Year.	Declination
	° ′		° ′
1808	6 40	1818	6 00
1809	6 40	1819	6 03
1810	6 35	1820	6 00
1811	6 30	1821	6 07
1812	6 26	1822	6 12
1813	6 25	1823	6 30
1814	6 17	1824	6 40
1815	6 07	1825	6 35
1816	6 03	1826	6 35
1817	6 02	1827	6 45

Data for determination of secular variation—Continued.

NEW HAMPSHIRE—Continued.

CHESTERFIELD—Continued.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1828	6 52	1838	8 00
1829	7 00	1839	8 05
1830	7 06	1840	8 10
1831	7 10	1841	8 15
1832	7 15	1842	8 15
1833	7 30	1843	8 15
1834	7 35	1844	8 12
1835	7 45	1847	8 20
1836	7 53	1890	11 13
1837	8 00		

HANOVER.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1839	9 15	1876	11 05
1855	10 27	1879	11 38
1873	10 50		

KEENE.

[From Samuel Wadsworth, surveyor Cheshire County.]

	° ′		° ′
1888	11 10	1892	11 30
1889	11 15	1893	11 33
1890	11 18	1894	11 45
1891	11 22	1895	11 52

PORTSMOUTH.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1833	8 45	1859	11 15
1845	9 47	1879	12 31
1850	10 30		

Data for determination of secular variation—Continued.

VERMONT.

Burlington.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1805	6 12	1834	8 50
1818	7 30	1840	9 42
1822	7 42	1845	9 22
1826	7 36	1855	9 57
1830	8 10	1870	10 57
1831	8 15	1873	11 19
1832	8 25		

Rutland.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1810	6 04	1873	10 40
1811	6 01	1879	11 09
1859	9 49		

MASSACHUSETTS.

Boston.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1807	6 05	1855	10 14
1833	8 00	1872	11 15
1839	9 06	1877	11 36
1846	9 31	1884	11 31

Cambridge.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1810	7 30	1850	9 30
1833	8 00	1852	10 08
1835	8 51	1854	10 39
1837	9 09	1855	10 54
1840	9 18	1856	10 50
1842	9 35	1859	10 48
1844	9 39	1867	10 41
1845	9 32	1879	11 46

Date for determination of secular variation—Continued.

MASSACHUSETTS—Continued.

NANTUCKET.

[Furnished by William F. Codd.]

Year.	Declination.	Year.	Declination.
	° ′		
1805	7 18	1878	12 20
1829	8 13	1879	12 30
1834	8 27	1880	12 30
1836	8 33	1881	12 45
1838	9 02	1882	12 45
1844	9 16	1883	12 34
1847	9 15	1884	12 45
1849	9 45	1885	12 40
1850	9 50	1886	12 30
1853	10 00	1887	12 18
1863	10 45	1888	12 30
1870	12 00	1889	12 46
1872	11 50	1891	12 30
1873	11 50	1892	12 30
1874	11 50	1893	12 40
1875	12 10	1894	12 45
1877	12 00		

NEWBURYPORT.

[From Coast and Geodetic Survey Report, 1888.]

1833	8 30	1859	10 58
1850	10 06	1887	12 12

PITTSFIELD.

The following series, furnished by Mr. A. A. Fobes, engineer for the Board of Public Works, is the result of a large number of comparisons of compasses made on a meridian line in the city of Pittsfield.

Year.	Declination	Remarks.
1871	8 51	Mean of 5 comparisons.
1872	9 02	Mean of 3 comparisons.
1873	9 00	Mean of 6 comparisons.
1874	9 10	Do.
1875	9 13	Mean of 4 comparisons.

Data for determination of secular variation—Continued.

MASSACHUSETTS—Continued.

PITTSFIELD—Continued.

Year.	Declination.	Remarks.
	° ′	
1876	9 02	Mean of 2 comparisons.
1877	9 08	1 comparison.
1878	9 12	Mean of 2 comparisons.
1879	9 00	1 comparison.
1880	9 20	Mean of 2 comparisons.
1881	9 20	1 comparison.
1882	9 35	Do.
1883	9 55	Mean of 2 comparisons.
1884	9 49	Do.
1885	9 46	Do.
1886	9 57	Mean of 3 comparisons.
1887	9 52	Mean of 4 comparisons.
1888	9 58	Mean of 2 comparisons.
1889	9 57	Do.
1890	10 00	Do.
1891	10 05	Mean of 4 comparisons.
1892	10 09	Mean of 6 comparisons.
1893	10 20	Mean of 3 comparisons.
1894	10 20	Do.
1895	10 26	Mean of 5 comparisons.

PROVINCETOWN.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1833	8 15	1860	11 24
1835	9 20		

SALEM.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1805	5 57	1849	10 14
1808	5 20	1855	10 50
1810	5 57	1877	11 30
1833	8 30	1887	12 38

Data for determination of secular variation—Continued.

MASSACHUSETTS—Continued.

Waltham

The following series is the result of comparisons of compasses upon a meridian line at Waltham. It was furnished by Francis H. Kendall, county engineer.

Year.	Declination.	Remarks.
	° ′	
1872	11 20	Mean of 6 comparisons.
1873	11 22	Mean of 3 comparisons.
1876	11 30	Mean of 2 comparisons.
1877	11 45	1 comparison.
1878	11 30	Do.
1882	11 25	Mean of 3 comparisons.
1884	11 41	Mean of 2 comparisons.
1887	11 57	Do.
1889	12 00	Do.
1890	12 07	Mean of 3 comparisons.
1891	12 23	1 comparison.
1893	12 25	Mean of 5 comparisons.
1895	12 22	Mean of 2 comparisons.

Williamstown.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1833	6 15	1876	10 31
1837	7 45	1886	10 21

Worcester.

The following series, furnished by the engineer of Worcester County, represents the means of large numbers of compass comparisons upon a meridian line established in the city of Worcester:

Year.	Declination.	Remarks.
	° ′	
1871	10 27	Mean of 3 comparisons.
1872	10 16	Mean of 18 comparisons.
1873	10 12	Mean of 8 comparisons.
1874	10 24	Mean of 10 comparisons.
1875	10 32	Mean of 5 comparisons.
1876	10 22	Mean of 8 comparisons.
1877	10 26	Do.
1878	10 45	Mean of 4 comparisons.

Data for determination of secular variation—Continued.

MASSACHUSETTS—Continued.

Worcester—Continued.

Year.	Declination	Remarks.
	° ′	
1879	10 45	Mean of 8 comparisons.
1880	10 50	Mean of 11 comparisons.
1881	10 58	Mean of 4 comparisons.
1882	10 59	Mean of 7 comparisons.
1883	11 00	Mean of 5 comparisons.
1884	10 55	Mean of 7 comparisons.
1885	10 57	Mean of 6 comparisons.
1886	11 09	Mean of 4 comparisons.
1887	10 58	Do.
1888	11 19	Mean of 7 comparisons.
1889	11 09	Mean of 5 comparisons.
1890	11 10	Mean of 10 comparisons.
1891	11 20	1 comparison.
1892	11 29	Mean of 5 comparisons.
1893	11 22	Mean of 3 comparisons.
1894	11 21	Do.
1895	11 38	Do.

RHODE ISLAND.

Providence.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1800	6 15	1840	8 25
1805	6 19	1841	8 31
1810	6 24	1842	8 39
1815	6 30	1843	8 46
1819	6 37	1855	9 31
1825	6 51	1884	11 08
1830	7 10	1885	11 10
1835	7 34		

CONNECTICUT.

Hartford.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1810	4 46	1859	7 17
1824	5 45	1867	7 49
1828	6 03	1879	8 34
1829	6 03		

Data for determination of secular variation—Continued.

CONNECTICUT—Continued.

New Haven.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1811	5 10	1845	6 17
1819	4 25	1848	6 34
1828	5 17	1855	7 03
1835	5 41	1872	8 27
1836	5 55	1878	8 41
1837	5 50	1884	8 55
1840	6 10	1885	9 00
1844	5 45		

Putnam.

[Reported by Mr. Edgar Clark.]

	° ′		° ′
1810	5 30	1866	9 30
1840	7 45		

NEW YORK.

Albany.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1817	5 44	1836	6 47
1818	5 45	1847	7 35
1825	6 00	1855	7 55
1828	6 16	1856	8 39
1830	6 18	1858	8 17
1831	6 32	1879	9 52
1834	6 40		

Buffalo.

[From Coast and Geodetic Survey Report, 1888.]

1837	1 25	1872	3 52
1839	1 15	1873	3 58
1845	1 25	1885	5 01
1859	2 56		

Data for determination of secular variation—Continued.

NEW YORK—Continued.

CANANDAIGUA.

[From M. T. Clark, surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1802	1 30	1890	6 00

COLD SPRING HARBOR, L. I.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1818	4 52	1864	7 47
1844	6 30	1886	8 34

KINGSTON.

[From Mr. Edward B. Codwise.]

	° ′		° ′
1884	9 12	1893	9 40

NEW YORK CITY.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1824	4 40	1846	5 20
1834	4 50	1847	5 41
1837	5 40	1855	6 43
1840	5 27	1860	6 44
1841	6 06	1873	7 09
1842	5 32	1874	7 23
1844	6 13	1879	7 32
1845	6 25	1885	7 53

OWEGO.

[From Mr. Asa Stanton, surveyor.]

	° ′		° ′
1877	6 32	1888	7 01
1882	6 37	1889	7 03
1883	6 36	1890	7 03
1884	6 32	1891	7 03
1885	6 45	1892	7 03
1886	6 52	1895	7 15
1887	6 52		

Data for determination of secular variation—Continued.

NEW YORK—Continued.

OXFORD, CHENANGO COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1817	3 00	1857	5 44
1828	4 30	1858	5 47
1834	3 52	1873	6 52
1837	4 30	1874	6 56
1838	4 27	1885	7 43
1849	5 11		

PIERREPONT MANOR.

[From Coast and Geodetic Survey Report. 1888.]

	° ′		° ′
1823	2 16	1866	6 15
1847	4 23	1867	6 10
1856	5 10	1868	6 10
1860	5 36	1869	6 18
1863	5 44	1870	6 04
1864	5 50	1874	6 33
1865	6 00		

ROCHESTER.

[From J. Y. McClintock, city engineer.]

	° ′		° ′
1876	5 41	1896	6 22
1893	6 42		

NEW JERSEY.

The following series are taken from volume 1 of the final report of the Geological Survey of New Jersey.

MOUNT HOLLY, BURLINGTON COUNTY.

[From comparisons of instruments on a meridian line.]

Year.	Declination.	Remarks.
	° ′	
1866	5 36	Mean of 10 comparisons.
1870	6 00	Mean of 15 comparisons.
1873	6 10	Mean of 10 comparisons.
1875	6 12	Mean of 16 comparisons.
1877	6 32	Mean of 9 comparisons.
1879	6 42	Do.
1881	6 50	Mean of 12 comparisons.
1882	6 53	Mean of 11 comparisons.
1885	6 57	Mean of 16 comparisons.

Data for determination of secular variation—Continued.

NEW JERSEY—Continued.

CAPE MAY, CAPE MAY COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1846	3 05	1857	3 30
1849	3 05	1874	4 38
1850	3 11	1881	5 06
1855	3 45	1888	5 11

BRIDGETON, CUMBERLAND COUNTY.

Year.	Declination.	Remarks.
	° ′	
1846	2 59	
1872	4 51	Mean of 17 observations.
1884	5 18	Mean of 9 observations.

WOODBURY, GLOUCESTER COUNTY.

Year.	Declination.	Remarks.
	° ′	
1846	3 45	
1865	4 48	
1867	4 49	Mean of 23 observations.
1870	4 46	
1874	5 11	Mean of 15 observations.
1883	6 01	Mean of 4 observations.

JAMESBURG, MIDDLESEX COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1815	3 12	1829	3 52
1826	3 50	1887	7 25

NEW BRUNSWICK, MIDDLESEX COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1800	2 24	1850	5 23
1804	2 30	1863	6 09
1811	3 19	1864	6 10
1814	3 07	1866	6 00
1815	3 13	1870	6 24
1830	3 34	1880	7 15
1836	4 40	1884	7 30
1838	4 45	1886	7 30
1846	5 23	1887	7 32
1848	5 10		

Data for determination of secular variation—Continued.

NEW JERSEY—Continued.

SANDY HOOK, MONMOUTH COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1842	5 32	1873	7 09
1844	5 51	1879	7 32
1855	6 11	1885	7 53

SOMERVILLE, SOMERSET COUNTY.

	° ′		° ′
1864	5 45	1869	6 00
1865	5 50	1870	6 00
1866	6 15	1873	6 27
1867	5 55	1887	7 19
1868	5 58		

HARDWICK, WARREN COUNTY.

	° ′		° ′
1866	6 03	1881	6 58
1868	6 10	1886	7 11
1870	6 18		

PENNSYLVANIA.

The following series are, except where noted, derived from the report of the Secretary of Internal Affairs of Pennsylvania for the year 1887:

ADAMS COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1847	2 15	1877	3 45

BEDFORD, BEDFORD COUNTY.

	° ′		° ′
1850	1 30	1883	3 34

HOLLIDAYSBURG, BLAIR COUNTY.

	° ′		° ′
1854	2 32	1873	3 45
1859	2 35	1887	4 27
1861	3 00		

Data for determination of secular variation—Continued.

PENNSYLVANIA—Continued.

TOWANDA, BRADFORD COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1856	4 30	1895	*a* 7 35
1878	5 30		

a County surveyor.

NEW YORK LINE, BRADFORD COUNTY.

	° ′		° ′
1863	5 23	1878	6 20

WESTCHESTER, CHESTER COUNTY.

	° ′		° ′
1832	3 25	1875	5 45
1852	4 25	1878	5 52

CLARION, CLARION COUNTY.

	° ′		° ′
1853	1 00	1877	2 20

CLEARFIELD COUNTY.

	° ′		° ′
1852	1 57	1878	3 46

CARLISLE, CUMBERLAND COUNTY.

	° ′		° ′
1854	2 10	1883	4 15
1877	3 56		

HARRISBURG, DAUPHIN COUNTY.

	° ′		° ′
1840	3 12	1874	4 51
1843	2 35	1876	*a* 5 10
1854	3 06	1877	4 53
1857	3 19	1881	*a* 5 17
1860	3 30	1885	5 21
1862	3 44	1889	*a* 5 30

a Coast and Geodetic Survey.

Data for determination of secular variation—Continued.

PENNSYLVANIA—Continued.

WILCOX, ELK COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1852	2 00	1887	4 20

UNION, FAYETTE COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1852	1 08	1873	2 30
1855	1 30	1879	2 47
1860	1 40	1880	2 50
1871	2 19	1881	3 00

CHAMBERSBURG, FRANKLIN COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1807	0 40 E.	1869	*a* 2 40
1809	0 45	1871	*a* 2 55
1816	0 30	1873	*a* 3 00
1818	0 30	1875	3 12
1822	*a* 0 15	1876	*a* 3 12
1825	0 15 E.	1877	*a* 3 20
1830	1 15 W.	1878	*a* 3 24
1836	*a* 0 27	1879	*a* 3 31
1840	*a* 0 54	1880	*a* 3 36
1850	1 30	1881	*a* 3 41
1852	*a* 1 42	1882	*a* 3 45
1859	*a* 2 12	1883	*a* 3 49
1860	2 10	1884	*a* 3 49
1863	*a* 2 15	1885	*a* 3 54
1864	*a* 2 19	1886	*a* 3 55
1865	*a* 2 24	1887	*a* 3 58
1866	*a* 2 25	1895	*b* 4 40
1867	*a* 2 35		

a Coast and Geodetic Survey. *b* County surveyor.

McCONNELSBURG, FULTON COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1856	2 00	1885	4 10
1884	4 05		

Data for determination of secular variation—Continued.

PENNSYLVANIA—Continued.

WAYNESBORO, GREENE COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1852	0 45	1883	2 29
1876	2 03		

INDIANA, INDIANA COUNTY.

	° ′		° ′
1852	0 50	1887	3 45

LEBANON COUNTY.

	° ′		° ′
1851	3 30	1876	4 52

WILLIAMSPORT, LYCOMING COUNTY.

	° ′		° ′
1841	3 00	1874	4 50
1873	4 46	1878	5 15

SOMERSET, SOMERSET COUNTY.

	° ′		° ′
1855	1 00	1887	3 45
1875	2 45		

LEWISBURG, UNION COUNTY.

	° ′		° ′
1869	4 11	1887	5 35
1878	5 00		

HATBORO, MONTGOMERY COUNTY.

	° ′		° ′
1800	1 55	1830	3 00
1810	2 00	1840	3 50
1820	2 27	1850	4 25

Data for determination of secular variation—Continued.

PENNSYLVANIA—Continued.

PHILADELPHIA.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1802	1 30	1862	*a* 5 00
1804	2 00	1872	*a* 5 28
1813	2 25	1877	6 08
1837	3 52	1884	*a* 6 22
1855	4 32	1895	*b* 6 44

a Coast and Geodetic Survey. *b* County surveyor.

LEWISBURG, MIFFLIN COUNTY.

	° ′		° ′
1851	1 55	1864	2 25
1852	1 50	1866	2 55
1854	2 00	1876	3 36
1857	2 11	1894	*a* 4 30
1861	2 50		

a County surveyor.

WASHINGTON, WASHINGTON COUNTY.

	° ′		° ′
1852	0 14	1874	1 40
1856	0 25	1875	1 58
1857	0 25	1878	1 40
1867	1 15	1883	2 36
1871	1 26	1886	2 30
1873	1 20	1887	2 31

BROOKVILLE, JEFFERSON COUNTY.

The following series, furnished by James B. Caldwell, county surveyor, is derived from compass comparisons on a meridian at Brookville:

Year.	Declination.	Year.	Declination.
	° ′		° ′
1851	1 00	1860	1 15
1852	1 10	1861	1 30
1854	1 10	1862	1 30
1855	1 00	1863	1 30
1856	1 00	1864	1 30
1857	1 30	1865	1 45
1858	1 30	1866	2 00
1859	1 20	1867	1 50

Data for determination of secular variation—Continued.

PENNSYLVANIA—Continued.

BROOKVILLE, JEFFERSON COUNTY—Continued.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1868	2 00	1882	3 10
1869	2 08	1883	3 18
1870	2 20	1884	3 20
1871	2 22	1885	3 30
1872	2 20	1886	3 30
1873	2 30	1888	3 30
1874	2 45	1889	3 37
1875	2 45	1890	3 40
1876	2 45	1891	3 44
1877	2 53	1892	3 39
1878	2 50	1893	3 48
1879	3 00	1894	3 50
1880	3 03	1895	3 58
1881	3 06		

YORK, YORK COUNTY.

The following series, furnished by the county surveyor, Mr. Edward Gross, contains the results of compass comparisons made on a meridian line at York:

Year.	Declination.	Remarks.
	° ′	
1875	4 47	Mean of 5 comparisons.
1876	4 59	Do.
1877	5 01	Do.
1878	5 05	Do.
1879	5 12	Mean of 3 comparisons.
1880	5 15	Mean of 4 comparisons.
1881	5 17	Mean of 3 comparisons.
1882	5 25	Mean of 2 comparisons.
1883	5 22	Do.
1884	5 30	Mean of 4 comparisons.
1885	5 30	Mean of 3 comparisons.
1886	5 34	Mean of 4 comparisons.
1887	5 34	Do.
1888	5 42	Mean of 3 comparisons.
1889	5 35	1 comparison.
1890	5 45	Mean of 2 comparisons.
1891	5 40	Mean of 3 comparisons.
1892	5 55	Mean of 2 comparisons.
1893	5 57	Mean of 4 comparisons.
1894	5 37	Mean of 3 comparisons.
1895	6 09	Do.

Data for determination of secular variation—Continued.

PENNSYLVANIA—Continued.

HONESDALE, WAYNE COUNTY.

Observations from 1885 to 1895, inclusive, are from compass comparisons on a meridian line, furnished by Mr. L. S. Collins, county surveyor.

Year.	Declination.	Remarks.
	° ′	
1855	5 29	
1876	6 45	
1885	7 37	Mean of 8 comparisons.
1886	7 39	Mean of 6 comparisons.
1887	7 31	Do.
1888	7 37	Mean of 7 comparisons.
1889	7 36	Mean of 5 comparisons.
1890	7 40	Mean of 7 comparisons.
1891	7 42	Mean of 5 comparisons.
1892	7 46	Mean of 6 comparisons.
1893	7 53	Do.
1894	7 56	Mean of 7 comparisons.
1895	8 03	Mean of 5 comparisons.

GREENSBURG, WESTMORELAND COUNTY.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1854	1 00	1884	3 07
1876	2 30		

TYRONE, BLAIR COUNTY.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1871	3 09	1875	3 26
1873	3 22	1878	3 42
1874	3 20	1879	3 52

BETHLEHEM, NORTHAMPTON COUNTY.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		
1841	3 26	1881	5 52
1851	3 50	1882	6 05
1871	5 19	1884	6 06
1878	5 37		

Data for determination of secular variation—Continued.

PENNSYLVANIA—Continued.

HUNTINGDON, HUNTINGDON COUNTY.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1840	1 52	1880	4 15
1849	1 59	1881	4 23
1852	2 16	1883	4 34
1858	2 34	1884	4 37
1860	2 41	1885	4 38
1874	3 31	1887	4 38
1879	4 07		

BEAVER, BEAVER COUNTY.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1866	0 37	1879	1 31
1874	1 08	1883	1 42

PITTSBURG, ALLEGHENY COUNTY.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1840	0 08	1884	2 41
1845	0 33	1885	2 56
1878	2 22		

ERIE, ERIE COUNTY.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1841	0 30	1875	2 10
1855	1 33	1876	2 50
1859	1 39	1877	3 00
1862	1 32	1883	3 20
1867	2 13	1885	3 08
1873	2 18		

Data for determination of secular variation—Continued.

DELAWARE.

Cape Henlopen.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1833	1 15	1856	3 04
1843	2 26	1885	5 00
1846	2 45		

Estimate of secular change by surveyor of Dover County, 3′ per year.

MARYLAND.

Baltimore.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1808	0 12	1875	3 45
1840	2 16	1877	4 11
1847	2 19	1885	4 29
1856	2 29		

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
Allegany	3
Frederick	3′

DISTRICT OF COLUMBIA.

Washington.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1809	0 52	1862	2 39
1841	1 20	1863	2 42
1842	1 24	1866	2 44
1855	2 24	1867	2 48
1856	2 21	1868	2 51
1857	2 25	1869	2 53
1860	2 27	1870	2 54

Data for determination of secular variation—Continued.

DISTRICT OF COLUMBIA—Continued.

WASHINGTON—Continued.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1871	2 57	1880	3 55
1872	3 00	1882	3 55
1873	3 00	1883	4 00
1874	3 06	1884	4 01
1875	3 15	1885	4 11
1876	3 19	1886	4 09
1877	3 39	1887	4 05
1878	3 45	1888	4 09
1879	3 50	1889	4 15

VIRGINIA.

CAPE HENRY.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1809	0 00	1881	3 11
1832	0 35	1883	3 22
1856	1 28	1884	3 46
1874	2 40	1887	3 20
1879	2 32		

WILLIAMSBURG, JAMES CITY COUNTY.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1809	0 33 E.	1874	2 12
1840	0 45 W.	1887	3 03

HARRISONBURG, ROCKINGHAM COUNTY.

[From J. Hawse, county surveyor.]

	° ′		° ′
1879	1 40	1895	2 32

HOUSTON, HALIFAX COUNTY.

[From Marcellus French, county surveyor.]

	° ′		° ′
1886	1 28	1895	2 00

Data for determination of secular variation—Continued.

VIRGINIA—Continued.

KING WILLIAM, KING WILLIAM COUNTY.

[From L. D. Robinson, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1876	2 45	1890	2 35
1878	2 48	1892	2 50
1880	3 10	1895	2 58
1885	2 55	1896	3 15

LURAY, PAGE COUNTY.

[From F. T. Amiss, county surveyor.]

	° ′		° ′
1840	0 00	1895	3 35

MATHEWS, MATHEWS COUNTY.

[From Lemuel Foster, county surveyor.]

	° ′		° ′
1819	0 45 E.	1883	2 32 W.
1852	2 21 W.	1895	4 56 W.

SPOTSYLVANIA COUNTY.

[From J. M. Smith, county surveyor.]

	° ′		° ′
1875	2 30	1895	3 30

STAUNTON, AUGUSTA COUNTY.

The following is a table of magnetic declination at different dates, prepared by J. R. McCutchen, county surveyor, for his own use, from experience in retracing old surveys:

Year.	Declination.	Year.	Declination.
	° ′		° ′
1800	2 05 E.	1850	0 42
1805	2 05	1855	0 25 E.
1810	2 05	1860	0 07 E.
1815	2 00	1865	0 13 W.
1820	1 54	1870	0 32
1825	1 47	1875	0 50
1830	1 39	1880	1 09
1835	1 26	1885	1 28
1840	1 13	1890	1 45
1845	0 58	1895	2 00

Data for determination of secular variation—Continued.

VIRGINIA—Continued.

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Accomac	3.0
Caroline	3.7
Carroll	3.3
Craig	2.3
Fauquier	3.5
Franklin	2.8
Greene	3.0
Lancaster	3.0
Loudoun	3.0
Nansemond	2.3
Pittsylvania	3.3
Stafford	3.3

WEST VIRGINIA.

HANCOCK COUNTY.

[From county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1849	0 15	1875	1 50
1858	0 30	1895	2 50

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Barbour	3.5
Braxton	3.1
Calhoun	3.0
Greenbrier	3.3
Giles	2.4
Mineral	4.0
Pocahontas	3.5
Putnam	2.9
Randolph	3.0
Taylor	3.0
Tucker	3.0
Tyler	2.5
Webster	3.0

Data for determination of secular variation—Continued.

NORTH CAROLINA.

NEWBERN.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1806	2 00 E.	1874	1 20 W.
1809	1 45 E.	1887	1 54 W.
1840	0 00		

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Washington	3.0
Stanly	3.0
Columbus	3.0
Alleghany	1.8
Haywood	2.5
Catawba	3.0
Transylvania	3.0
Randolph	2.0
Currituck	3.0
Person	3.3
Halifax	3.0
Brunswick	3.0
Gaston	3.0
Wilkes	2.6

SOUTH CAROLINA.

CHARLESTON.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1824	3 45	1847	2 15
1833	4 00	1849	2 17
1837	2 54	1874	0 58
1840	2 44	1880	0 26
1841	2 24	1885	0 14

Data for determination of secular variation—Continued.

SOUTH CAROLINA—Continued.

BEAUFORT, BEAUFORT COUNTY.

[From George Gage.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1863	2 30	1895	1 00

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Spartanburg	3.0
Orangeburg	3.7

GEORGIA.

MILLEDGEVILLE.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1805	5 30	1875	4 14
1835	4 40	1887	3 36
1838	5 51		

SAVANNAH.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1817	4 00	1852	3 40
1833	5 00	1857	3 27
1838	5 05	1874	2 17
1839	3 31	1886	1 37

ATHENS, CLARKE COUNTY.

	°		°
1837	*a* 4.30	1896	*b* 1.42
1882	*b* 2.31		

a Georgia Geological Survey. *b* County surveyor.

Data for determination of secular variation—Continued.

GEORGIA—Continued.

BUTTS COUNTY.

[From county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1821	5 15	1895	2 00
1879	2 30		

CAMDEN COUNTY.

[From James F. King, jr., county surveyor.]

	° ′		° ′
1810	0 0	1895	4 15

CLAYTON COUNTY.

[From W. J. Lee, county surveyor.]

	° ′		° ′
1820	5 00	1893	2 00

CLINCH COUNTY.

[From S. R. Kirton, county surveyor.]

	° ′		° ′
1820	5 00	1895	1 30

FANNIN COUNTY.

[From C. G. Baugh, county surveyor.]

	° ′		° ′
1832	5 30	1895	2 30

FAYETTEVILLE, FAYETTE COUNTY.

[From R. H. Bennett, county surveyor.]

	° ′		° ′
1815	5 30	1895	3 30

GILMER COUNTY.

[From M. S. Clayton, county surveyor.]

	° ′		° ′
1835	5 00	1896	2 00

Data for determination of secular variation—Continued.

GEORGIA—Continued.

Glascock County.

[From Wilson Glover, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1860	2 00	1863	2 00
1895		1895	
1873	1 45		
1894			

The above are changes discovered in rerunning old lines.

Jones County.

[From S. L. Chiles, county surveyor.]

	° ′		° ′
1822	5 30	1895	2 00
1885	2 30		

Milledgeville, Baldwin County.

[From G. W. Killen, county surveyor.]

	° ′		° ′
1840	5 00	1895	2 00

Spalding County.

[From M. F. Tutuilla, county surveyor.]

	° ′		° ′
1821	5 20	1896	1 36

Stilesboro, Bartow County.

[From H. J. McCormick, county surveyor.]

	° ′		° ′
1855	4 30	1895	2 30

Troup County.

[From Roy Dallas, county surveyor.]

	° ′		° ′
1826	5 00	1885	3 00
1860	4 30	1890	2 45
1870	4 00	1895	2 30
1883	3 15		

Data for determination of secular variation—Continued.

GEORGIA—Continued.

WALTON COUNTY.

[From C. M. Booth, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1819	5 30	1890	2 10
1885	2 20	1895	2 00

The following are estimates of secular variation by county surveyors from experience:

Counties.	Sec. var. per year.
	′
Banks	3.0
Bartow	3.0
Towns	2.8
Washington	2.0

FLORIDA.

PENSACOLA.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1817	8 45	1861	6 42
1843	6 54	1880	5 20
1858	6 47	1890	4 55

KEY WEST.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1829	6 25	1864	4 34
1843	6 02	1865	4 32
1849	5 29	1866	4 30
1860	4 47	1879	3 34
1861	4 44	1884	3 00
1862	4 40	1887	3 20
1863	4 37		

Data for determination of secular variation—Continued.

FLORIDA—Continued.

FLORAL, CITRUS COUNTY.

[From G. T. Hampton, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1849	4 30	1894	2 35

ORLANDO, ORANGE COUNTY.

[From J. O. Fries, county surveyor.]

	° ′		° ′
1879	3 05	1890	2 36
1885	2 48	1893	2 27

SUWANEE COUNTY.

[From county surveyor.]

	° ′		° ′
1825	6 10	1895	2 30

The following are from a comparison of county surveyors' results with mean results of Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Alachua	1835–1895	60	163
Brevard	1870–1895	25	88
Citrus	1855–1894	39	91
Marion	1842–1890	48	132
Orange	1865–1893	28	76
Osceola	1858–1891	33	75
Polk	1850–1895	45	166
Suwanee	1863–1895	32	105

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Putnam	3.3
Polk	3.5
Madison	3.0
Brevard	3.0

Data for determination of secular variation—Continued.

ALABAMA.

Florence.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1818	6 35	1875	5 14
1835	6 28	1881	4 38
1865	5 24		

Mobile.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1809	8 10	1857	6 52
1835	7 12	1875	6 07
1840	7 05	1883	5 12
1843	6 56	1895	*a* 4 45
1847	7 04		

a County surveyor.

Pike County.

[From I. M. Adams, county surveyor.]

	° ′		° ′
1870	5 45	1895	4 15

Randolph County.

[From county surveyor.]

	° ′		° ′
1832	6 00	1895	2 30

Sumter County.

[From J. F. Williamson, county surveyor.]

	° ′		° ′
1833	8 00	1895	5 30
1873	6 37		

Marion, Perry County.

[From D. E. Bates, county surveyor.]

	° ′		° ′
1850	6 30	1892	4 15
1852	4 30		

Data for determination of secular variation—Continued.

ALABAMA—Continued.

COOSA COUNTY.

[From D. B. Brown, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1832	6 00	1895	2 30
1855	5 00		

The following are from a comparison of county surveyors' returns with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Coosa	1832–1895	63	240
Dallas	1844–1895	51	167
Hale	1842–1895	43	110
Macon	1832–1888	56	155
Marengo	1842–1895	53	135
Mobile	1846–1895	59	135
Perry	1845–1895	50	155
Randolph	1834–1895	61	178

MISSISSIPPI.

NATCHEZ.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1802	9 00	1878	7 23
1872	7 15		

COLUMBUS, LOWNDES COUNTY.

[From C. L. Wood, county surveyor.]

	° ′		° ′
1832	7 47	1895	5 20

COMO, PANOLA COUNTY.

[From Robert Ruffin, county surveyor.]

	° ′		° ′
1840	7 42	1887	5 45

Data for determination of secular variation—Continued.

MISSISSIPPI—Continued.

JACKSON, HINDS COUNTY.

[From R. H. Bell, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1820	8 33	1895	5 41

JONES COUNTY.

[From county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1810	8 00	1895	5 00

PEARL RIVER COUNTY.

[From P. J. Harvey, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1874	7 20	1893	5 20

ROLLING FORK, SHARKEY COUNTY.

[From W. M. Hull, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1827	8 40	1895	6 10

SMITH COUNTY.

[From S. D. Crapt, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1832	8 10	1895	5 30
1883	6 15		

WINONA, MONTGOMERY COUNTY.

[From Jesse C. Elliott, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1832	8 10	1891	6 03
1885	6 25	1896	5 48

Data for determination of secular variation—Continued.

MISSISSIPPI—Continued.

The following are from a comparison of county surveyors' results with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Benton	1834–1896	62	170
Harrison	1842–1895	53	152
Lauderdale	1833–1895	62	151
Montgomery	1833–1896	63	78
Newton	1831–1895	64	151

LOUISIANA.

New Orleans.

[From Coast and Geodetic Survey Report.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1806	8 03	1870	7 06
1840	8 20	1872	6 46
1856	8 00	1880	6 28
1858	7 51		

Abbeville, Vermilion Parish.

[From W. W. Edwards, parish surveyor.]

	° ′		° ′
1846	8 30	1889	6 45
1878	7 45	1895	6 30
1884	7 00		

East Baton Rouge Parish.

[From R. Swart, parish surveyor.]

	° ′		° ′
1870	7 50	1895	5 56
1884	6 15		

Data for determination of secular variation—Continued.

LOUISIANA—Continued.

EAST CARROLL PARISH.

[From parish surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1835	8 30	1895	6 30

LINCOLN PARISH.

[From parish surveyor.]

	° ′		° ′
1873	8 00	1895	7 00

MOREHOUSE PARISH.

[From A. E. Washburn, parish surveyor.]

	° ′		° ′
1850	9 30	1892	6 40
1860	8 50	1893	6 35
1870	7 50	1894	6 34
1880	7 15	1895	6 32
1890	6 45		

TANGIPAHOA PARISH.

[From Thomas Garahy, parish surveyor.]

	° ′		° ′
1858	7 30	1895	6 00

The following are from a comparison of parish surveyors' results with mean results from Land Office surveys:

Parish.	Years.	Difference in—	
		Years.	Declination.
			′
Ascension	1847–1896	49	142
East Baton Rouge	1854–1896	42	126
East Carroll	1846–1894	48	100
St. James	1845–1896	51	150
St. John the Baptist	1848–1896	48	153
St. Tammany	1848–1895	47	127
Tangipahoa	1840–1895	55	117
West Baton Rouge	1844–1896	52	114

Data for determination of secular variation—Continued.

TEXAS.

El Paso.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1852	12 24	1884	12 05
1859	12 25	1888	11 54
1878	12 25	1895	*a* 11 43

a County surveyor.

San Antonio.

[From Coast and Geodetic Survey Report.]

	° ′		° ′
1825	10 30	1878	9 22
1836	9 45	1895	*a* 9 45
1874	9 30		

a County surveyor.

Bandera, Bandera County.

[From A. L. Scott, county surveyor.]

	° ′		° ′
1845	9 45	1895	8 55

Beaumont, Jefferson County.

[L. F. Daniels, county surveyor.]

	° ′		° ′
1830	9 20	1895	8 10

Brenham, Washington County.

[From H. R. Von Bieberstein, county surveyor.]

	° ′		° ′
1860	9 45	1891	8 42

Carthage, Panola County.

[From J. B. Niel, county surveyor.]

	° ′		° ′
1838	9 20	1895	8 00

Data for determination of secular variation—Continued.

TEXAS—Continued.

Fredericksburg, Gillespie County.

[From Arthur Striegler, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1849	10 30	1886	9 23
1870	10 05	1887	9 22
1878	9 51	1888	9 19
1880	9 49	1889	9 15
1881	9 47	1890	9 14
1882	9 34	1891	9 10
1883	9 31	1893	9 10
1884	9 27	1894	8 57
1885	9 25	1895	8 54

Goliad County.

[From county surveyor.]

	° ′		° ′
1838	9 45	1895	8 15
1856	9 30		

Gonzales, Gonzales County.

[From G. W. Betts, county surveyor.]

	° ′		° ′
1832	10 38	1894	9 20

Goodwin, Comal County.

[From Arthur Conrads, county surveyor.]

	° ′		° ′
1840	9 45	1895	8 30

Graham, Young County.

[From C. P. Benson, county surveyor.]

	° ′		° ′
1859	11 03	1894	9 49

Grayson County.

[From county surveyor.]

	° ′		° ′
1872	9 52	1894	9 46

Data for determination of secular variation—Continued.

TEXAS—Continued.

HALLETTSVILLE, LAVACA COUNTY.

[From H. H. Russell, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1831	10 30	1894	8 45

LIVINGSTON, POLK COUNTY.

[From R. W. Hubert, county surveyor.]

	° ′		° ′
1835	9 30	1895	8 00

NACOGDOCHES, NACOGDOCHES COUNTY.

[From J. N. Gilbert county surveyor.]

	° ′		° ′
1858	9 10	1895	8 00

PLAINVIEW, HALE COUNTY.

[From W. E. Porterfield, county surveyor.]

	° ′		° ′
1875	12 15	1895	11 30

PECOS COUNTY.

[From W. B. Bean, county surveyor.]

	° ′		° ′
1882	11 00	1896	10 30

RAYNER, STONEWALL COUNTY.

[From J. J. Hale, county surveyor.]

	° ′		° ′
1886	10 00	1895	9 45

ROBERTSON COUNTY.

[From J. J. Fullbright, county surveyor.]

	° ′		° ′
1855	10 00	1895	8 50

Data for determination of secular variation—Continued.

TEXAS—Continued.

SAN PATRICIO, SAN PATRICIO COUNTY.

[From county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1873	9 05	1896	8 10

SEYMOUR, BAYLOR COUNTY.

[From W. A. Jones, county surveyor.]

	° ′		° ′
1872	10 45	1895	9 34

SPOFFORD, KINNEY COUNTY.

[From C. F. Hodges, county surveyor.]

	° ′		° ′
1848	9 45	1888	9 10
1858	9 38	1890	9 13
1867	9 38		

SOMERVELL COUNTY.

[From George D. Booker, county surveyor.]

	° ′		° ′
1849	9 30	1895	9 15

SWEETWATER, NOLAN COUNTY.

[From Lee Fowler, county surveyor.]

	°		° ′
1853	10 30	1895	7 30

TARRANT COUNTY.

[From J. J. Goodfellow, county surveyor.]

	° ′		° ′
1852	9 50	1891	8 20

VALVERDE COUNTY.

[From J. H. Brauer, county surveyor.]

	° ′		° ′
1848	9 45	1895	9 30

Data for determination of secular variation—Continued.

TEXAS—Continued.

The following are estimates of secular variations by county surveyors:

County.	Sec. var. per year.
	′
Limestone	2.0
Dewitt	2.5
Bee	2.5
Coleman	1.8

ARKANSAS.

Craighead County.

[From T. C. Cole, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1815	8 00	1895	4 35

Hot Springs, Garland County.

[From county surveyor.]

	° ′		° ′
1873	8 40	1895	7 26

Hot Springs County.

[From county surveyor.]

	° ′		° ′
1856	7 30	1895	5 50
1880	6 30		

Newton County.

[From John Nichols, county surveyor.]

	° ′		° ′
1845	8 00	1895	6 30
1853	7 11	1895	5 30

Perry County.

[From county surveyor.]

	° ′		° ′
1845	8 00	1895	6 00

Data for determination of secular variation—Continued.

ARKANSAS—Continued.

POPE COUNTY.

[From W. R. Hale, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1828	8 00	1895	6 00
1838	7 40		

YELL COUNTY.

[From W. W. Brooks, county surveyor.]

	° ′		° ′
1825	8 00	1895	6 05

[1] The following are from a comparison of county surveyors' results with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Benton	1844–1894	50	63
Craighead	1849–1895	46	145
Drew	1844–1895	51	53
Faulkner	1847–1895	48	158
Do	1828–1895	67	170
Garland	1845–1895	50	54
Hot Springs	1850–1895	45	95
Jackson	1840–1895	55	130
Madison	1841–1895	54	110
Nevada	1822–1895	73	143
Ouachita	1853–1895	42	105
Do	1829–1895	66	129
Perry	1843–1895	52	135
Do	1836–1895	59	125
Pope	1843–1895	52	100
Prairie	1847–1895	48	155
Randolph	1852–1895	43	140
Washington	1844–1895	51	96
Woodruff	1843–1895	52	106
Yell	1839–1895	56	116

Data for determination of secular variation—Continued.

ARKANSAS—Continued.

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Arkansas	2.3
Benton	3.0
Craighead	2.4

KENTUCKY.

Hickman, Fulton County.

[From A. C. Holmes, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1881	5 47	1892	5 14
1887	5 30	1895	5 04

Madison County.

[From B. F. Crooke, county surveyor.]

	° ′		° ′
1827	6 00	1895	1 45

Winchester, Clark County.

[From D. J. Pendleton, county surveyor.]

	° ′		° ′
1882	3 22	1895	2 28
1890	2 49		

Data for determination of secular variation—Continued.

KENTUCKY—Continued.

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Crittenden	2.3
Cumberland	2.0
Fleming	3.0
Garrard	3.0
Hancock	2.0
Magoffin	3.0
Mason	3.5
Monroe	2.4
McLean	2.0
Rowan	2.0
Simpson	3.0
Todd	2.8
Warren	2.5
Webster	3.0

TENNESSEE.

Nashville.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1829	6 50	1888	4 31
1835	7 07	1896	*a*4 06
1877	5 15		

a County surveyor.

Davidson County.

[From Lyle and Balls, county surveyors.]

	° ′		° ′
1835	7 07	1871	5 35
1840	6 42	1884	5 00
1848	6 20	1888	4 52
1859	6 04	1896	4 06
1867	5 30		

Data for determination of secular variation—Continued.

TENNESSEE—Continued.

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Bedford	3.5
Bledsoe	2.4
Carter	3.0
Coke	3.0
Fentress	3.0
Giles	2.0
Grundy	2.5
Haywood	2.0
Houston	2.0
Humphreys	2.0
Jackson	1.8
Knox	3.0
Monroe	3.0
Overton	4.0
Robertson	4.0
Sullivan	3.4
Washington	3.0

OHIO.

ATHENS.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1806	4 17	1880	0 40
1838	3 12		

CINCINNATI.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1806	4 58	1815	4 04
1810	5 00	1880	2 14
1840	4 46	1888	1 58

Data for determination of secular variation—Continued.

OHIO—Continued.

CLEVELAND.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year	Declination.
	° ′		° ′
1830	1 20 E.	1859	0 46 W.
1831	1 15	1871	0 33
1834	0 50	1872	0 45
1838	0 35	1873	0 51
1840	0 19	1876	1 08
1841	0 05	1880	1 39
1845	0 39 E.	1888	2 04

CHILLICOTHE, ROSS COUNTY.

[From B. H. Walker, county surveyor.]

	° ′		° ′
1887	0 36	1892	0 07
1888	0 35	1893	0 02
1889	0 33	1894	0 02
1890	0 24	1895	0 10
1891	0 13		

HAMILTON, HAMILTON COUNTY.

[From J. C. Weaver, county surveyor.]

	° ′		° ′
1835	4 00	1895	0 44

LEBANON, WARREN COUNTY.

[From P. O. Monfort, county surveyor.]

	° ′		° ′
1869	3 10	1886	2 24
1870	3 22	1887	2 16
1871	3 08	1888	2 11
1872	3 02	1889	2 08
1879	2 45	1890	1 58
1881	2 57	1891	1 37
1882	2 30	1892	1 33
1883	2 28	1893	1 27
1884	2 24	1894	1 09
1885	2 22	1895	1 10

Data for determination of secular variation—Continued.

OHIO—Continued.

LYRA, SCIOTO COUNTY.

[From county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1874	0 20 E.	1895	0 44 W.

OTTAWA, PUTNAM COUNTY.

[From J. D. Huddle, county surveyor.]

	° ′		° ′
1820	4 25	1895	0 00
1869	2 00		

WAVERLY, PIKE COUNTY.

[From H. W. Overman, county surveyor.]

	° ′		° ′
1800	5 33	1895	0 00

The following are from a comparison of county surveyors' results with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Auglaize	1828–1883	55	183
Carroll	1802–1895	93	240
Darke	1801–1895	94	184
Hamilton	1799–1895	96	266
Hardin	1820–1874	54	165
Ottawa	1821–1877	56	188
Putnam	1825–1895	70	260
Richland	1807–1894	87	341
Seneca	1821–1895	74	221
Wayne	1807–1840	33	60
Williams	1822–1895	73	242

Data for determination of secular variation—Continued.

INDIANA.

Michigan City.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1830	5 35	1871	4 02
1859	5 23	1873	3 59

Liberty, Union County.

[From county surveyor.]

	° ′		° ′
1837	4 20	1895	1 30
1868	3 45		

Richmond, Wayne County.

[From R. A. Howard, county surveyor.]

	° ′		° ′
1880	2 52	1896	1 53
1886	2 36		

The following are from a comparison of county surveyors' results with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination
			′
Allen	1832–1894	62	176
Blackford	1823–1895	72	229
Jennings	1809–1895	86	228
Johnson	1821–1894	73	204
Knox	1808–1880	72	134
Lake	1834–1895	61	132
Marion	1821–1880	59	190
Morgan	1821–1896	75	240
Posey	1806–1895	89	200
Putnam	1820–1895	75	226
Spencer	1805–1895	90	160
Union	1800–1895	95	217
Vigo	1815–1888	73	180
Warrick	1806–1895	89	180
Wayne	1809–1896	87	197
White	1831–1895	64	160

Data for determination of secular variation—Continued.

ILLINOIS.

Chicago.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1823	6 12	1878	4 33
1857	5 46	1888	4 07

Aledo, Mercer County.

[From William B. Frew, county surveyor.]

	° ′		° ′
1865	7 10	1895	4 40

America, Pulaski County.

[From J. P. Mathis, county surveyor.]

	° ′		° ′
1848	7 00	1896	4 45
1888	5 08		

Barry, Pike County.

[From A. G. Chamberlain.]

	° ′		° ′
1879	6 25	1892	5 15
1880	6 20	1895	5 00
1885	5 45		

Belleville, St. Clair County.

[From county surveyor.]

	° ′		° ′
1830	8 30	1880	6 35
1850	8 00	1890	5 45
1860	7 50	1895	5 20
1870	7 35		

Effingham County.

[From J. B. Jones, county surveyor.]

	° ′		° ′
1850	6 45	1895	4 15

Data for determination of secular variation—Continued.

ILLINOIS—Continued.

ELVASTON, HANCOCK COUNTY.

[From J. H. Horney, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1867	7 35	1895	5 32

GALESBURG, KNOX COUNTY.

[From C. S. Richey, county surveyor.]

	° ′		° ′
1854	7 25	1895	5 25
1880	6 00		

GREENFIELD, GREENE COUNTY.

[From T. G. Capps, county surveyor.]

	° ′		° ′
1819	8 10	1895	5 10
1865	7 10		

GREENVILLE, BOND COUNTY.

[From R. K. Dewey, county surveyor.]

	° ′		° ′
1858	7 30	1895	5 20

HARDIN COUNTY.

[From W. H. Scroggins, county surveyor.]

	° ′		° ′
1806	7 30	1885	5 00

JEFFERSON COUNTY.

[From W. F. Williams, county surveyor.]

	° ′		° ′
1865	6 30	1895	4 00

Data for determination of secular variation—Continued.

ILLINOIS—Continued.

Olney, Richland County.

[From G. W. Armsey, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1818	7 30	1895	4 00

Peoria County.

[From D. B. Allen, county surveyor.]

	° ′		° ′
1817	8 10	1895	5 45

Rushville, Schuyler County.

[From Jeremiah Stumm, county surveyor.]

	° ′		° ′
1815	8 10	1872	6 30
1842	7 30	1895	5 15
1864	7 15		

Stark County.

[From county surveyor.]

	° ′		° ′
1817	8 10	1864	6 45
1854	7 15	1895	5 00

Vandalia, Fayette County.

[From A. H. Wing, county surveyor.]

	° ′		° ′
1869	6 10	1895	4 45

Vienna, Johnson County.

[From county surveyor.]

	° ′		° ′
1806	7 30	1885	4 40

Data for determination of secular variation—Continued.

ILLINOIS—Continued.

WAYNESVILLE, DEWITT COUNTY.

[From John S. Brown, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1867	6 34	1892	4 45

The following are from a comparison of county surveyors' returns with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Bureau	1827–1893	66	203
Cook	1829–1888	59	192
Fayette	1823–1895	72	195
Grundy	1821–1892	71	154
McHenry	1839–1894	55	154
McLean	1824–1896	72	275
Putnam	1826–1895	69	194
Richland	1821–1895	74	220
Vermilion	1821–1895	74	255

MICHIGAN.

DETROIT.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1810	2 48 E.	1865	0 40
1822	3 13	1872	0 25
1828	2 50	1873	0 17
1835	2 10	1876	0 05 E.
1840	1 58	1885	0 31 W.
1859	0 42		

GRAND HAVEN.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1837	5 08	1871	3 33
1859	4 21	1873	3 28
1865	4 20	1880	2 26

Data for determination of secular variation—Continued.

MICHIGAN—Continued.

SAULT STE. MARIE.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1819	2 33 E.	1856	0 32 E.
1843	1 08	1873	0 05 W.
1844	1 01	1879	1 01
1845	0 46	1880	1 00
1846	0 40		

YPSILANTI.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1815	4 00 E.	1863	0 25 E.
1825	3 16	1875	0 30 W.
1832	2 40	1878	0 45
1838	2 25	1881	1 00
1851	1 12	1885	1 13
1855	1 00	1887	1 25
1859	0 45	1888	1 30
1860	0 38		

CASS COUNTY.

[From F. E. Smith, county surveyor.]

	° ′		° ′
1853	4 00	1896	1 40
1880	2 45		

HILLSDALE COUNTY.

[From George A. Mark, county surveyor.]

The following are differences observed in rerunning old lines.

Years.	Change.	Years.	Change.
	° ′		° ′
1879–1884	0 33	1880–1884	0 30
1879–1884	0 25	1869–1881	1 10
1871–1875	0 24	1870–1879	0 45
1871–1886	1 25	1877–1884	0 33
1871–1878	0 36	1884–1893	0 38
1871–1881	0 51	1877–1893	1 34
1880–1884	0 24	1876–1880	0 21
1880–1884	0 18	1881–1896	1 06

Data for determination of secular variation—Continued.

MICHIGAN—Continued.

KALAMAZOO, KALAMAZOO COUNTY.

[From Marcus Baker.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1826	5 50 E.	1884	2 47
1834	5 48	1890	1 55
1879	3 13	1893	1 39
1880	2 46	1895	1 32

LEELANAW COUNTY.

[From Kasson Freeman, county surveyor.]

	° ′		° ′
1862	2 15	1895	0 22

PENTWATER, OCEANA COUNTY.

[From H. A. Grant, county surveyor.]

	° ′		° ′
1838	6 20	1895	1 45
1892	2 00		

SHIAWASSEE COUNTY.

[From H. C. Main, county surveyor.]

	° ′		° ′
1864	1 30	1887	0 16

CALHOUN COUNTY.

[From county surveyor.]

	° ′		° ′
1825	5 30	1893	1 04

Data for determination of secular variation—Continued.

MICHIGAN—Continued.

DELTA COUNTY.

[From county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1847	4 30 E.	1888	2 30 E.
1847	1 30 W.	1888	3 00 W.
1847	4 30 E.	1888	2 00 E.
1846	3 00 E.	1888	1 15 E.
1847	11 30 E.	1888	8 30 E.
1846	3 30 E.	1887	1 10 E.
1846	3 45 E.	1894	0 45 E.
1845	1 34 E.	1894	2 00 W.
1847	3 15 E.	1895	1 00 E.
1846	4 00 E.	1895	1 00 E.
1846	4 00 E.	1895	2 00 E.
1846	4 00 E.	1895	2 30 E.
1846	1 45 E.	1895	4 00 W.
1846	6 00 W.	1895	10 00 W.
1847	4 30 E.	1895	0 35 E.
1852	4 30 E.	1895	3 00 E.

The following are from a comparison of county surveyors' results with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Allegan	1832–1871	39	194
Barry	1829–1896	67	247
Cass	1829–1896	67	225
Clinton	1831–1895	64	237
Grand Traverse	1844–1893	49	154
Hillsdale	1825–1896	71	271
Kalamazoo	1827–1890	63	208
Lenawee	1822–1896	74	274
Mecosta	1841–1895	54	170
Monroe	1827–1895	68	172
Oakland	1819–1895	76	305
Oceana	1839–1895	56	183

Data for determination of secular variation—Continued.

WISCONSIN.

Madison.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1839	7 30	1879	6 27
1841	7 30	1880	6 21
1876	7 00	1881	6 21
1877	6 45	1888	5 53
1878	6 33		

Milwaukee.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1859	6 20	1882	4 55
1871	6 43	1888	4 22
1873	6 22		

Appleton, Outagamie County.

[By F. J. Harriman, county surveyor.]

	° ′		° ′
1843	6 12	1895	3 35

Iowa County.

[From R. L. Joiner, county surveyor.]

	° ′		° ′
1848	8 00	1880	6 20
1862	7 00	1895	5 30

Juneau County.

[From J. T. Patterson, county surveyor.]

	° ′		° ′
1851	8 00	1895	5 00

Kewaunee, Kewaunee County.

[From W. T. Rodney, county surveyor.]

	° ′		° ′
1832	6 20	1895	2 20

Data for determination of secular variation—Continued.

WISCONSIN—Continued.

MONROE COUNTY.

[From Webster Kenyon, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1855	8 32	1895	6 32

OAKLAND, JEFFERSON COUNTY.

[From C. S. Goodrich.]

	° ′		° ′
1851	7 20	1885	5 20

ONEIDA COUNTY.

[From D. H. Vaughn, county surveyor.]

	° ′		° ′
1860	7 00	1895	3 45

OZAUKEE COUNTY.

[From county surveyor.]

	° ′		° ′
1848	6 30	1895	4 30

SHEBOYGAN, SHEBOYGAN COUNTY.

[From county surveyor.]

	° ′		° ′
1857	6 15	1894	3 20
1865	6 05		

TAYLOR COUNTY.

[From John A. Logan, county surveyor.]

Results from rerunning old lines.

	° ′		° ′
1847	8 00	1891	5 30
1847	7 30	1891	5 22
1857	8 00	1890	6 30
1857	7 30	1891	5 30
1854	6 45	1884	4 16
1854	7 00	1884	4 31
1854	8 00	1895	5 41
1854	8 30	1895	6 24

Data for determination of secular variation—Continued.

WISCONSIN—Continued.

VICTORY, VERNON COUNTY.

[From C. M. Sterling, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1870	7 35	1895	6 04

The following are from a comparison of county surveyors' results with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Calumet	1837-1895	58	115
Columbia	1836-1895	59	175
Green	1834-1894	60	222
Jefferson	1836-1885	49	90
Outagamie	1839-1895	56	158
Rock	1834-1892	58	185
Sauk	1839-1893	54	210
Sheboygan	1835-1894	59	220

The following are estimates of secular variation by county surveyors:

County.	Sec. var. per year.
	′
Adams	3.0
Barron	3.5
Jefferson	3.5
Waupaca	4.3
Winnebago	2.8

MINNESOTA.

BENTON COUNTY.

[From county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1884	9 50	1895	9 10

Data for determination of secular variation—Continued.

MINNESOTA—Continued.

LESUEUR COUNTY.

[From Edward Solberg.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1855	12 00	1895	9 50

NEW ULM, BROWN COUNTY.

[From county surveyor.]

	° ′		° ′
1855	11 23	1895	8 27

ST. CLOUD, STEARNS COUNTY.

[From M. P. Noel, county surveyor.]

	° ′		° ′
1855	11 30	1895	8 30

WATONWAN COUNTY.

[From Otto Close, county surveyor.]

	° ′		° ′
1862	11 20	1895	9 25

The following are from a comparison of county surveyors' returns with mean returns from Land Office surveys:

County	Years.	Difference in—	
		Years.	Declination.
			′
Benton	1853–1895	42	96
Bigstone	1869–1895	26	170
Blue Earth	1854–1894	40	100
Brown	1858–1895	37	115
Cottonwood	1859–1896	37	130
Dodge	1854–1895	41	105
Fillmore	1853–1895	42	153
Goodhue	1855–1895	40	170
Martin	1855–1894	39	100
Ottertail	1868–1896	28	113
Ramsey	1847–1890	43	90
Stearns	1857–1895	38	147
Watonwan	1856–1894	38	61

Data for determination of secular variation—Continued.

MINNESOTA—Continued.

The following are estimates of secular variation from county surveyors:

County.	Sec. var. per year.
	′
Fillmore	3.3
Anoka	3.6
Blue Earth	2.5
Bigstone	3.0

IOWA.

AFTON, UNION COUNTY.

[From M. V. Ashby, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1849	10 22	1895	8 40

BLOOMFIELD, DAVIS COUNTY.

[From Thomas Duffield, county surveyor.]

	° ′		° ′
1855	9 35	1895	8 10

BRIDGEWATER, ADAIR COUNTY.

[From George F. Clark, county surveyor.]

From 1854 to 1895 declination diminished 1° 30′.

CLARENCE, CEDAR COUNTY.

[From John Zuck, county surveyor.]

	° ′		° ′
1884	7 45	1895	6 45
1889	7 20		

CLARINDA, PAGE COUNTY.

[From A. S. van Sandt, county surveyor.]

	° ′		° ′
1851	11 55	1893	9 12

Data for determination of secular variation—Continued.

IOWA—Continued.

CLARKE COUNTY.

[From county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1850	9 30	1895	8 00

DELHI, DELAWARE COUNTY.

[From D. O. Potter, county surveyor.]

	° ′		° ′
1837	8 25	1893	5 25

DEWITT, CLINTON COUNTY.

[From R. G. Brown, county surveyor.]

	° ′		° ′
1878	6 30	1895	5 00
1888	5 45		

DUBUQUE, DUBUQUE COUNTY.

[From county surveyor.]

	°		° ′
1874	7 25	1895	6 30

GILLETT GROVE, CLAY COUNTY.

[From P. M. Moore, county surveyor.]

	° ′		° ′
1855	11 30	1893	8 45

GLENWOOD, MILLS COUNTY.

[From Seth Dean, county surveyor.]

	° ′		° ′
1851	11 17	1881	10 10
1853	11 12	1882	10 30
1858	11 14	1883	10 10
1860	11 13	1884	10 46
1873	10 27	1885	10 34
1878	10 47	1889	10 20
1879	10 35	1895	9 33
1880	10 42	1896	9 26

Data for determination of secular variation—Continued.

IOWA—Continued.

HAMPTON, FRANKLIN COUNTY.

[From William F. Kelley, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1851	8 17	1895	5 50

MANSON, CALHOUN COUNTY.

[From county surveyor.]

	° ′		° ′
1853	11 30	1895	9 25

The following are from a comparison of county surveyors' returns with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Cedar	1838–1895	57	138
Clay	1857–1893	36	131
Dubuque	1839–1895	56	130
Keokuk	1843–1895	52	132
Pocahontas	1855–1894	39	127
Wapello	1844–1895	51	144

MISSOURI.

ST. LOUIS.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1819	10 48	1877	6 30
1835	8 49	1878	6 31
1838	7 45	1879	6 13
1856	6 23	1886	6 11
1872	6 37		

CASS COUNTY.

[From county surveyor.]

	° ′		° ′
1843	8 00	1896	6 15

Data for determination of secular variation—Continued.

MISSOURI—Continued.

CLARK COUNTY.

[From O. F. Ensign, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1820	8 15	1866	7 08
1836	8 00	1895	6 05
1855	7 30		

FRANKLIN COUNTY.

[From C. L. Moore, county surveyor.]

	° ′		° ′
1817	8 00	1895	4 30

HOWELL COUNTY.

[From T. F. Adams, county surveyor.]

	° ′		° ′
1845	7 53	1896	5 15

MORGAN COUNTY.

[From D. W. Eaton, county surveyor.]

	° ′		° ′
1858	7 21	1893	5 06
1858	7 19	1893	5 24
1859	6 45	1894	4 56
1855	7 28	1881	6 28
1854	6 53	1890	5 36
1855	7 30	1893	6 00
1851	7 57	1890	6 36

PEMISCOT COUNTY.

[From W. W. Tensley, county surveyor.]

	° ′		° ′
1847	7 42	1895	5 17

Data for determination of secular variation—Continued.

MISSOURI—Continued.

Perry County.

[From T. H. Layton, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1818	8 00	1896	4 45

Shannon County.

[From T. J. Rowlett, county surveyor.]

	° ′		° ′
1840	8 00	1895	5 15

Stone County.

[From William J. King, county surveyor.]

	° ′		° ′
1847	7 40	1895	5 30

Sullivan County.

[From Charles Reeves, county surveyor.]

	° ′		° ′
1854	9 45	1895	7 35

Taney County.

[From H. W. Strahan, county surveyor.]

	° ′		° ′
1872	7 01	1895	6 10
1886	6 30		

NORTH DAKOTA.

Nelson County.

[From D. S. Dodds, county surveyor.]

Year.	Declination.	Year.	Declination.
			° ′
1882	13 30	1895	13 00

Data for determination of secular variation—Continued.

NORTH DAKOTA—Continued.

Pembina County.

[From Frank E. Hebert, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1867	14 40	1890	12 40
1867	14 38	1883	12 52
1867	14 05	1895	11 45
1868	14 35	1895	11 45

SOUTH DAKOTA.

Codington County.

[From George W. Carpenter, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1879	10 15	1895	10 00
1887	10 08		

NEBRASKA.

Omaha.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1819	12 47	1878	10 30
1869	10 43	1880	10 06
1872	10 44	1888	9 30
1877	10 22		

Beatrice, Gage County.

[From Willis Ball, county surveyor.]

	° ′		° ′
1876	11 30	1895	11 02

Culbertson, Hitchcock County.

[From L. J. Carrington, county surveyor.]

	° ′		° ′
1872	13 35	1895	12 15
1883	13 00		

Data for determination of secular variation—Continued.

NEBRASKA—Continued.

BLAINE COUNTY.

[From M. Hollapeter, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1873	13 09	1895	12 00

JOHNSON COUNTY.

[From county surveyor.]

	° ′		° ′
1866	10 30	1894	8 10

OTOE COUNTY.

[From county surveyor.]

	° ′		° ′
1855	10 40	1895	8 55

The following are from a comparison of county surveyors' returns with mean results from Land Office surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Banner	1870–1895	25	77
Cass	1856–1895	39	75
Cheyenne	1870–1896	26	90
Hall	1862–1893	31	89
Hitchcock	1870–1895	25	72
Jefferson	1856–1895	39	145
Nemaha	1855–1896	41	60
Phelps	1865–1896	31	90
Platte	1857–1895	38	143
Sarpy	1856–1895	39	65

KANSAS.

ANTHONY, HARPER COUNTY.

[From J. B. Lee, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		
1873	10 50	1896	9 50

Data for determination of secular variation—Continued.

KANSAS—Continued.

BURLINGTON, COFFEY COUNTY.

[From H. E. Robson, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1881	10 36	1894	9 32
1891	9 43	1895	9 33
1892	9 41	1896	9 24
1893	9 44		

BUTLER COUNTY.

[From T. H. Austin, county surveyor.]

	° ′		° ′
1876	10 25	1895	9 35

DODGE, FORD COUNTY.

[From John G. Fonda, county surveyor.]

	° ′		° ′
1870	12 00	1895	10 30

DONIPHAN COUNTY.

[From E. S. Castle, county surveyor.]

	° ′		° ′
1855	11 30	1895	9 55

EDWARDS COUNTY.

[From Cyrus Roberts, county surveyor.]

	° ′		° ′
1873	11 30	1895	10 45

EUREKA, GREENWOOD COUNTY.

[From H. E. Robb, county surveyor.]

	° ′		° ′
1881	10 43	1889	9 57
1882	10 17	1890	9 42
1883	10 13	1891	9 44
1884	10 03	1892	9 52
1885	9 47	1893	9 38
1886	9 55	1894	9 28
1887	9 52	1895	9 31
1888	9 45		

Data for determination of secular variation—Continued.

KANSAS—Continued.

JETMORE, HODGEMAN COUNTY.

[From A. L. Hull, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1880	11 45	1888	11 21
1881	11 46	1889	11 20
1882	11 55	1890	11 20
1883	11 44	1891	11 14
1884	11 27	1892	11 04
1885	11 28	1893	11 00
1886	11 22	1894	11 07
1887	11 21	1895	11 09

LINDON, OSAGE COUNTY.

[From S. H. McNeil, county surveyor.]

	° ′		° ′
1870	11 11	1882	10 25
1871	11 13	1883	10 12
1872	11 25	1884	10 10
1873	10 05	1887	9 57
1874	10 17	1888	9 50
1875	10 15	1889	9 45
1876	9 56	1890	9 43
1877	9 47	1891	9 45
1878	10 12	1892	9 55
1879	10 18	1893	8 45
1880	10 15	1894	9 31
1881	10 27		

MARYSVILLE, MARSHALL COUNTY.

[From John Braly, county surveyor.]

	° ′		° ′
1881	10 35	1891	9 31
1886	10 02	1892	9 21
1887	10 00	1893	9 21
1888	9 36	1894	9 20
1889	9 40	1895	9 20
1890	9 33		

Data for determination of secular variation—Continued.

KANSAS—Continued.

MOLINE, ELK COUNTY.

[From J. T. Chapman, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1870	10 45	1895	9 10

NEWTON, HARVEY COUNTY.

[From James Dawson, county surveyor.]

	° ′		° ′
1884	10 32	1892	10 15
1885	10 22	1894	10 23
1891	10 33	1895	10 18

OSBORNE, OSBORNE COUNTY.

[From A. A. Nolan, county surveyor.]

	° ′		° ′
1872	12 16	1887	11 00
1873	12 17	1888	11 00
1874	12 14	1889	11 00
1884	11 00	1891	11 04
1885	11 00	1894	11 02
1886	11 04	1895	10 57

PHILLIPSBURG, PHILLIPS COUNTY.

[From F. R. Weeks, county surveyor.]

	° ′		° ′
1882	11 58	1895	10 57

SALINA, SALINE COUNTY.

[From O. P. Hamilton, county surveyor.]

	° ′		° ′
1875	12 09	1886	11 17
1876	12 08	1887	11 30
1877	12 06	1888	11 24
1878	11 51	1889	11 26
1879	11 56	1890	11 25
1880	11 48	1891	11 25
1881	11 46	1892	11 07
1882	11 43	1893	11 00
1883	11 47	1894	10 49
1884	11 40	1895	10 48
1885	11 22	1896	10 30

Data for determination of secular variation—Continued.

KANSAS—Continued.

SMITH CENTER, SMITH COUNTY.

[From W. H. Withington, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1882	12 06	1889	11 53
1883	12 04	1890	11 51
1884	12 02	1891	11 49
1885	12 00	1892	11 48
1886	11 59	1893	11 46
1887	11 58	1894	11 45
1888	11 56	1895	11 39

ST. JOHN, STAFFORD COUNTY.

[From W. F. Noble, county surveyor.]

	° ′		° ′
1879	11 52	1888	10 46
1880	11 54	1890	10 48
1881	11 42	1891	10 44
1882	11 05	1892	10 40
1884	10 45	1893	10 36
1885	10 54	1894	10 33
1886	10 57	1895	10 35
1887	10 52	1896	10 31

WASHINGTON, WASHINGTON COUNTY.

[From T. C. Edington, county surveyor.]

	° ′		° ′
1857	12 30	1896	10 37

WEIR, CHEROKEE COUNTY.

[From W. H. Dugger, county surveyor.]

	° ′		° ′
1867	10 10	1896	8 30

WICHITA, SEDGWICK COUNTY.

[From W. R. Kesler, county surveyor.]

	° ′		° ′
1868	11 22	1895	10 30

Data for determination of secular variation—Continued.

KANSAS—Continued.

The following are from a comparison of county surveyors' returns with mean results from Land Office surveys:

County.	Years.	Difference in— Years.	Difference in— Declination.
			′
Atchison	1855–1892	37	145
Brown	1855–1893	38	93
Butler	1862–1893	31	108
Cherokee	1868–1896	28	142
Clay	1857–1895	38	151
Coffey	1856–1895	39	175
Dickinson	1856–1895	39	110
Doniphan	1855–1895	40	146
Edwards	1871–1895	24	80
Elk	1867–1895	28	137
Ellsworth	1859–1895	36	141
Ford	1872–1895	23	78
Gray	1872–1895	23	102
Greenwood	1867–1895	28	118
Harper	1876–1896	20	60
Harvey	1857–1895	38	102
Hodgeman	1870–1895	25	56
Jackson	1855–1895	40	129
Jewell	1862–1894	32	108
Linn	1856–1895	39	174
McPherson	1858–1894	36	150
Marion	1857–1893	36	115
Marshall	1855–1895	40	151
Meade	1873–1896	23	45
Ness	1869–1895	26	78
Osborne	1864–1895	31	71
Pawnee	1867–1893	26	94
Phillips	1859–1895	36	145
Pottawattomie	1855–1895	40	172
Reno	1859–1895	36	155
Rice	1866–1895	29	112
Riley	1856–1895	39	101
Rooks	1865–1895	30	97
Sedgwick	1859–1895	36	80
Sherman	1871–1888	17	51
Smith	1862–1895	33	96
Wabaunsee	1856–1892	36	100
Woodson	1867–1895	28	118

Data for determination of secular variation—Continued.

WYOMING.

Cheyenne.

Year.	Declination.	Year.	Declination.
	° ′		° ′
1873	15 30	1895	14 30

Laramie.

	° ′		° ′
1872	16 21	1888	14 57
1878	15 52	1895	14 24

COLORADO.

Denver.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1866	15 00	1878	14 40
1872	14 45	1888	14 06
1873	14 43		

Alma, Park County.

[From W. H. Powless, county surveyor.]

	° ′		° ′
1881	14 40	1895	13 50

The following are from a comparison of county surveyors' results with mean results of Land Office Surveys:

County.	Years.	Difference in—	
		Years.	Declination.
			′
Arapahoe, west part	1860–1888	28	59
Bent	1871–1888	17	40
Costilla	1871–1895	24	57
El Paso	1869–1886	17	33
Pueblo	1869–1888	19	84

Data for determination of secular variation—Continued.

ARIZONA.

Yuma, Yuma County.

[From O. F. Townsend, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1881	13 35	1893	13 45
1886	13 41		

Graham County.

[From Samuel Logan, county surveyor.]

Place.	Year.	Declination.
		° ′
Duncan	1882	12 30
	1895	12 10
Clifton	1882	12 30
	1895	12 17
Solomonville	1875	14 06
	1895	12 25
Safford	1875	14 06
	1895	12 30
Camp Grant	1886	12 30
	1895	12 25
Camp Thomas	1875	14 07
	1895	12 32

The following comparative results consist, for the earlier date, in the average of the observations taken within the county, or part of county, in connection with the survey of exteriors and standard lines by the General Land Office, and for the later date in connection with the survey of subdivision lines by the same organization:

County.	Year.	Difference in declination.
		′
Yuma (eastern part)	1877 1893	—55
Maricopa (eastern part)	1868 1893	—16
Maricopa (southwestern part)	1870 1892	—41
Maricopa (northwestern part)	1872 1883	— 5
Pinal (western part)	1869 1889	—50

Data for determination of secular variation—Continued.

ARIZONA—Continued.

The following comparative results are derived from the surveys by the General Land Office of the exterior lines of townships on the one hand, and on the other of the subdivision lines of the same townships.

Township.	Year	Difference in declination.
T. 11 N., R. 3 E	1873 1891	—36
T. 21 N., R. 17 W	1873 1891	—93
T. 3 N., R. 3 E	1868 1891	— 2
T. 3 N., R. 4 E	1869 1895	—21
T. 5 S., R. 7 E	1869 1891	—51
T. 6 S., R. 9 E	1869 1891	—50
T. 4 N., R. 1 E	1868 1894	—27
T. 4 N., R. 2 E	1868 1894	—26
T. 4 N., R. 3 E	1868 1894	— 2
T. 5 S., R. 7 W	1871 1892	—87
T. 6 S., R. 4 W	1872 1892	—38
T. 6 S., R. 5 W	1871 1891	—41
T. 6 S., R. 6 W	1872 1892	—78
T. 6 S., R. 7 W	1872 1892	—31
T. 4 S., R. 6 W	1871 1890	—12
T. 4 S., R. 10 W	1870 1892	—34

Data for determination of secular variation—Continued.

ARIZONA—Continued.

Of the following comparative results those of the earlier dates are derived from the expeditions of Lieut. J. C. Ives and Capt. W. H. Emory, those of the later dates from surveys of the General Land Office.

Township.	Year.	Difference in declination.
T. 5 S., R. 16 E	1851 1877	+81
T. 8 S., R. 23 W	1851 1874	+48
T. 2 S., R. 5 E	1851 1891	+ 8
T. 17 N., R. 21 E	1854 1879	+60
T. 18 N., R. 23 E	1854 1882	− 9
T. 19 N., R. 18 E	1854 1882	+30
T. 19 N., R. 17 E	1854 1882	+54
T. 19 N., R. 25 E	1854 1882	+39
T. 19 N., R. 28 E	1854 1882	+25
T. 20 N., R. 27 E	1854 1883	+40
T. 20 N., R. 25 E	1854 1883	+21
T. 21 N., R. 19 E	1854 1883	−10
T. 22 N., R. 6 E	1854 1889	+83
T. 21 N., R. 15 E	1854 1882	− 5
T. 22 N., R. 1 W	1854 1883	+15

Data for determination of secular variation—Continued.

UTAH.

SALT LAKE.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1850	15 34	1881	16 28
1866	16 30	1883	16 14
1869	16 36	1885	16 29
1872	17 00	1887	16 31
1878	16 46	1895	16 30

The following comparative results consist, for the earlier date, in the average of the observations taken within the county, or part of county, in connection with the survey of exteriors and standard lines by the General Land Office, and for the later date in connection with the survey of subdivision lines by the same organization:

County.	Year.	Difference in declination.
Summit (western part)	1871 1892	+20
Morgan	1870 1889	— 3
Beaver (eastern part)	1870 1890	—10
Salt Lake	1871 1890	—26
Sevier	1875 1891	—38
Wasatch (western part)	1872 1891	—16
Boxelder (eastern part)	1875 1888	+ 3
Boxelder (western part)	1874 1889	—29
Cache	1874 1894	— 2

Data for determination of secular variation—Continued.

NEVADA.

Douglas County.

[From M. Willard, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1885	16 50	1895	16 35

The following comparative results consist, for the earlier date, in the average of the observations taken within the county, or part of county, in connection with the survey of exteriors and standard lines by the General Land Office, and for the later date in connection with the survey of subdivision lines by the same organization:

County.	Year.	Difference in declination.
		′
Esmeralda (northern part)	1868 1890	−18
Eureka (southern part)	1868 1893	− 4
Humboldt (southeastern part)	1867 1888	+10
Humboldt (northeastern part)	1868 1888	+16
Humboldt (southwestern part)	1863 1890	+43
Lincoln (southeastern part)	1869 1882	00
Lincoln (southwestern part)	1870 1882	00
Nye (northeastern part)	1869 1881	−32
Washoe (southern part)	1864 1887	+50
White Pine (southwestern part)	1869 1882	− 7

Data for determination of secular variation—Continued.

IDAHO.

The following comparative results consist, for the earlier date, in the average of the observations taken within the county, or part of county, in connection with the survey of exteriors and standard lines by the General Land Office, and for the later date in connection with the survey of subdivision lines by the same organization:

County.	Year.	Difference in declination.
Ada	1867 1893	+3
Bear Lake	1873 1884	—17
Bannack (eastern part)	1874 1890	—12
Bannack (western part)	1874 1894	— 4
Boise (southern part)	1872 1892	+23
Canon	1867 1893	—30
Cassia (eastern part)	1872 1892	— 7
Elmore	1871 1892	+15
Idaho (western part)	1869 1893	+ 2
Latah	1871 1892	+66
Lincoln (eastern part)	1871 1892	—48
Nez Perce	1870 1892	+ 6
Owyhee (eastern part)	1870 1893	—47
Owyhee (northwestern part)	1870 1894	+17
Washington (southern part)	1869 1892	+52

Data for determination of secular variation—Continued.

WASHINGTON.

Cape Disappointment.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1839	19 11	1858	21 00
1842	20 00	1873	21 36
1851	20 32	1881	21 36

Neah Bay.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1841	22 30	1855	21 48
1852	21 30	1881	22 44

Olympia.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1853	21 15	1881	21 35
1856	20 47	1895	*a* 22 20

a County surveyor.

Port Townsend.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1841	20 40	1862	22 00
1856	21 40	1876	21 59
1857	21 54	1881	21 27

Seattle.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1855	21 25	1881	22 03
1871	22 35	1888	22 29

Vancouver.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1839	19 22	1860	20 05
1859	21 30	1881	20 53

Wallawalla.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1853	19 40	1881	21 00
1860	20 15	1887	21 10
1861	20 30		

Data for determination of secular variation—Continued.

WASHINGTON—Continued.

The following comparative results consist, for the earlier date, in the average of the observations taken within the county, or part of county, in connection with the survey of exteriors and standard lines by the General Land Office, and for the later date in connection with the survey of subdivision lines by the same organization:

County.	Year.	Difference in declination.
Lewis	1854 1890	+ 99
Cowlitz	1854 1892	+144
Mason	1854 1893	+ 90
Pierce	1857 1891	+ 77
Thurston	1856 1891	+ 51
King	1856 1891	+ 57
Snohomish	1858 1892	+ 78
Jefferson	1857 1893	+ 49
Pacific	1864 1891	+ 66
Yakima	1862 1892	− 57
Chehalis	1865 1892	+ 22
Klickitat	1864 1891	+161
Skagit	1866 1893	+ 38
Clallam	1862 1892	+ 10
Douglas	1867 1893	+ 67
Kittitas	1869 1891	+ 23

Data for determination of secular variation—Continued.

WASHINGTON—Continued.

The following comparative results are derived from the surveys by the General Land Office of the exterior lines of townships on the one hand, and on the other of the subdivision lines of the same townships:

Township.	Year.	Difference in declination.
		′
T. 20 N., R. 2 W	1853 1894	+100
T. 16 N., R. 3 W	1853 1891	+ 50
T. 14 N., R. 5 W	1856 1891	+101
T. 8-9 N., R. 14-20 E	1860 1893	+ 50
T. 33 N., R. 5 E	1861 1891	+ 34
T. 14 N., R. 8 W	1867 1891	+ 71
T. 16 N., R. 4 E	1867 1893	+ 72
T. 17 N., R. 5 E	1867 1890	— 24
T. 33 N., R. 5 E	1871 1891	+ 34
T. 23 N., R. 7 E	1872 1892	+ 60
T. 28 N., R. 8 E	1873 1891	+ 35

OREGON.

ALBANY, LINN COUNTY.

[From E. T. T. Fisher, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1870	19 48	1895	20 42

BENTON COUNTY.

[From George Mercer, county surveyor.]

	° ′		° ′
1855	19 30	1895	20 00

Data for determination of secular variation—Continued.

OREGON—Continued.

Hillsboro, Washington County.

[From L. E. Wilkes, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1852	20 10	1895	21 30

Marion County.

[From B. B. Herrick, county surveyor.]

	° ′		° ′
1852	20 15	1895	21 30

McMinnville, Yamhill County.

[From E. C. Branson, county surveyor.]

	° ′		° ′
1856	19 30	1885	20 30
1870	20 00	1895	20 35

Roseburg, Douglas County.

[From W. P. Heydon, county surveyor.]

	° ′		° ′
1880	19 03	1895	20 07

Tillamook, Tillamook County.

[From A. M. Austin, county surveyor.]

	° ′		° ′
1856	19 30	1893	21 54

Lane County.

[From C. M. Collier, county surveyor.

	° ′		° ′
1855	19 30	1895	20 30

CALIFORNIA.

Cape Mendocino.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1854	17 05	1886	18 00

Data for determination of secular variation—Continued.

CALIFORNIA—Continued.

MONTEREY.

[From Coast and Geodetic Survey Report, 1888.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1818	16 30	1843	14 00
1827	15 38	1851	14 58
1837	14 30	1854	14 59
1839	14 30	1873	15 55
1841	15 00	1881	15 54

SAN DIEGO.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1839	12 21	1872	13 19
1851	12 29	1881	13 28
1853	12 32	1888	13 04
1866	13 09		

SAN FRANCISCO.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1827	15 27	1873	16 25
1829	14 55	1874	16 27
1830	14 51	1879	16 34
1837	15 10	1880	16 33
1839	15 20	1881	16 30
1841	15 30	1883	16 39
1849	15 41	1884	16 32
1852	15 28	1885	16 33
1858	15 53	1886	16 33
1866	16 25	1887	16 34
1871	16 23	1888	16 34
1872	16 26	1889	16 36

SANTA BARBARA.

[From Coast and Geodetic Survey Report, 1888.]

	° ′		° ′
1839	13 28	1890	14 47
1869	15 12	1891	14 48
1881	14 52	1895	*a* 14 46

a County surveyor.

Data for determination of secular variation—Continued.

CALIFORNIA—Continued.

MERCED COUNTY.

[From W. P. Stoneroad, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1853	13 35	1895	15 47

MONO COUNTY.

[From J. G. Thompson, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1856	15 30	1895	16 35
1880	16 10		

ORANGE COUNTY.

[From H. C. Kellogg, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1868	14 32	1895	14 42
1888	14 50		

SAN JOSE, SANTA CLARA COUNTY.

[From J. G. McMillan, county surveyor.]

Year.	Declination.	Year.	Declination.
	° ′		° ′
1850	15 23	1868	16 00
1851	15 23	1872	16 25
1852	15 23	1874	16 25
1853	15 25	1875	16 35
1854	15 25	1876	16 30
1855	15 30	1880	16 30
1856	15 30	1882	16 30
1857	15 30	1884	16 30
1858	15 45	1886	16 30
1860	15 45	1888	16 30
1861	15 45	1890	16 30
1862	15 45	1893	16 35
1863	16 00	1895	16 35

YUBA, SUTTER COUNTY.

[From C. W. Guptill, county surveyor.]

Year.	Declination.	Year.	Declination.
1867	15 25	1894	15 15

METHOD OF OBTAINING REDUCTIONS ON ACCOUNT OF SECULAR VARIATION.

The above observations have been used in the simplest manner possible for the determination of the reduction for secular variation. The epoch selected for the reduction is the year 1900, and the observations are treated in the following manner: To the latest observation in each series was first applied a correction to reduce it to this epoch. To make this correction it was assumed that the annual secular variation in the Northern States has been for the past few years 4′ per year, in the States in middle latitudes 3.5′, and in those of the extreme South 3′ per year. These assumptions are practically correct, and any slight error in them would have but little effect on the reductions, inasmuch as it is multiplied by a small number of years only.

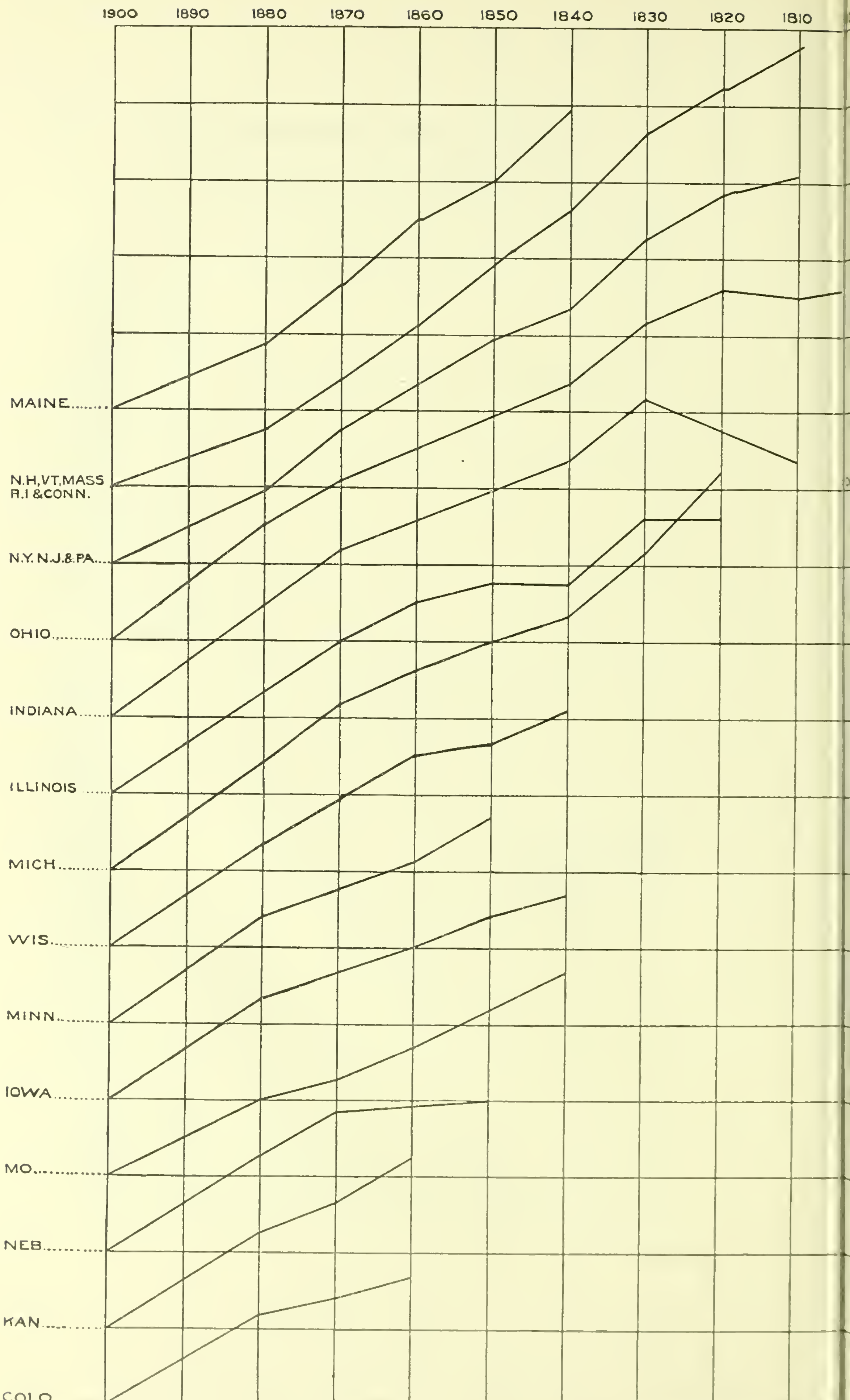
Having thus obtained from the latest observation of each series the declination in 1900, each observation in the series was then compared with it, and the resulting reduction was tabulated under the early date. All the series within a State were then combined into a single series, and a table was in this manner prepared for each State, or in certain cases for groups of States, which shows in extenso the reduction to 1900 for each year prior to 1895, or for each year in which there were observations. In this manner the series at many stations were consolidated. In order to eliminate accidental errors each State table was further consolidated into a smaller table, showing the reduction for each tenth year by simply taking the means of the observations for five years on each side of the decennial year. These are presented in the following table, and are expressed graphically in the diagrams on Pl. III. It must be said that in several cases these reductions do not accord with one another, nor do the reductions for the same year in different States agree with one another in all cases, the discrepancies being probably due to errors of observation. I have, however, considered it best to use them, applying the results State by State, rather than to make arbitrary corrections to bring them into closer agreement with one another.

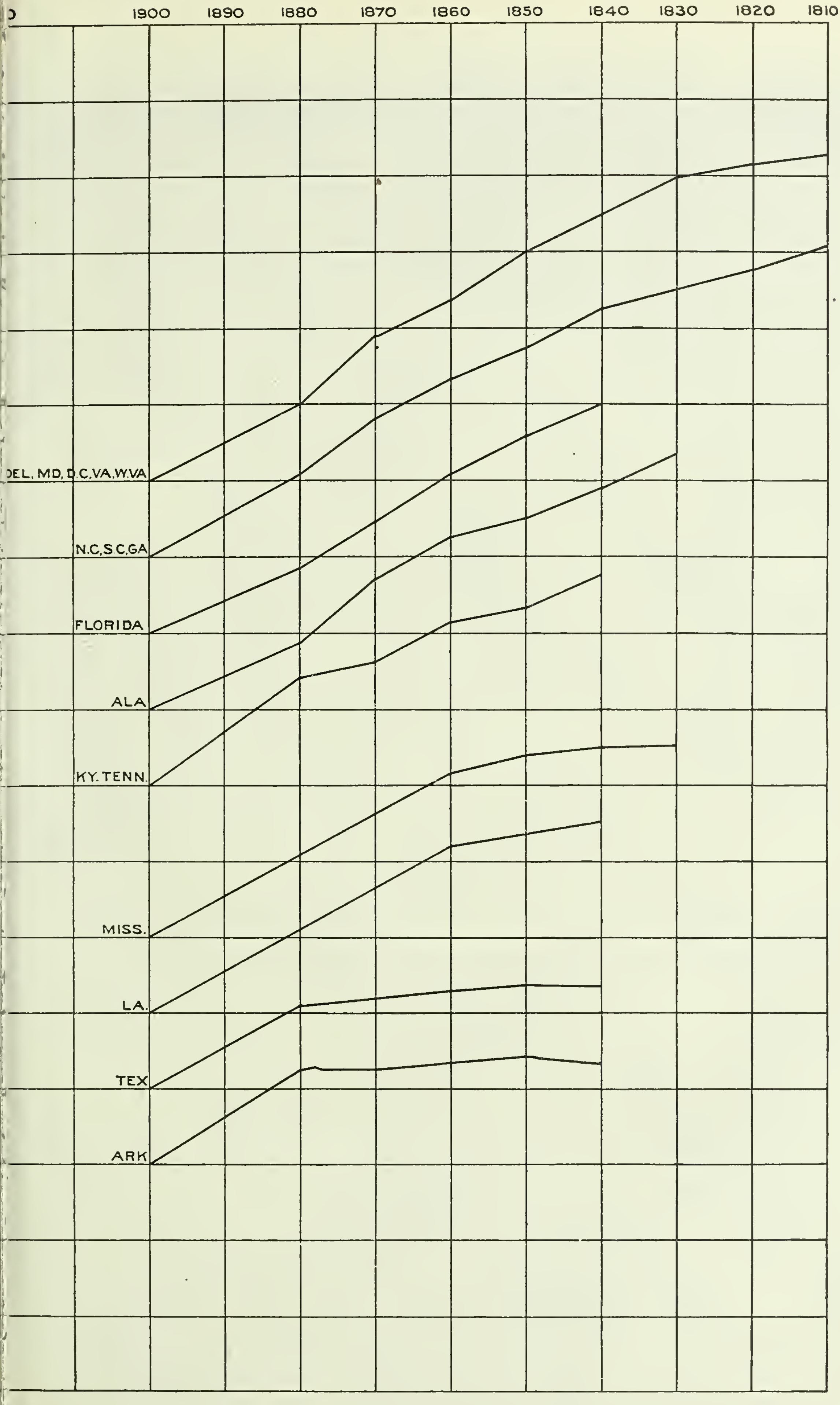
In obtaining these reductions I have thought it best to include in one group the States of western New England, viz, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut, in order to obtain the mean of many results; in another group the States of New York, New Jersey, and Pennsylvania; in another Delaware, Maryland, District of Columbia, Virginia, and West Virginia; in another the two Carolinas and Georgia, and in still another Kentucky and Tennessee. In the case of the Southern States, which are included in the last three groups named, it was necessary to group several States in order to obtain a sufficient number of series of observations to secure results of any value, and since by this grouping I have extended the areas considered but slightly in longitude, I do not believe that in so doing I have involved any appreciable error.

Reductions to 1900 on account of secular variation.

State.	1880.	1870.	1860.	1850.	1840.	1830.	1820.	1810.	1800.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Maine	0 50	1 45	2 30	3 00	3 55	......	.....	.....	.....
New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut	45	1 25	2 05	2 55	3 40	4 40	5 20	5 50	.....
New York, New Jersey, and Pennsylvania	50	1 45	2 20	2 55	3 20	4 15	4 50	5 05	.....
Delaware, Maryland, District of Columbia, Virginia, and West Virginia	1 00	1 55	2 25	3 00	3 30	4 00	4 10	4 20	.....
North Carolina, South Carolina, and Georgia	1 05	1 50	2 20	2 45	3 15	3 30	3 45	4 05	.....
Florida	50	....	2 05	2 35	3 00	......	.....	.....	.....
Alabama	50	1 40	2 15	2 30	2 55	3 20	.....	.....	.....
Mississippi	......	......	2 05	2 20	2 30	2 30	.....	.....	.....
Louisiana	......	......	2 10	2 20	2 30	......	.....	.....	.....
Texas	1 05	1 10	1 15	1 20	1 20	......	.....	.....	.....
Arkansas	1 15	1 15	......	1 25	1 20	......	.....	.....	.....
Kentucky and Tennessee	1 25	1 40	2 10	2 20	2 50	......	.....	.....	.....
Ohio	1 30	2 05	......	......	3 20	4 10	4 35	4 30	4 40
Indiana	......	2 10	......	......	......	3 20	4 10	3 45	3 20
Illinois	1 20	2 00	2 30	2 45	2 45	3 35	3 35	.....	.....
Michigan	1 25	2 10	2 35	3 00	3 20	4 10	4 50	.....	.....
Wisconsin	1 20	......	2 30	2 40	3 05	......	.....	.....	.....
Iowa	1 20	......	2 00	2 25	2 45	......	.....	.....	.....
Minnesota	1 25	......	2 05	2 40	......	......	.....	.....	.....
Missouri	1 00	1 15	1 10	2 10	2 40	......	.....	.....	.....
Nebraska	1 15	1 50	1 55	2 00	......	......	.....	.....	.....
Kansas	1 15	1 45	2 15	......	......	......	.....	.....	.....
Colorado (eastern part)	1 10	1 25	1 40	......	......	......	.....	.....	.....
Oregon and Washington (western part)	......	+ 45	+1 05	......	+2 30	......	.....	.....	.....
California (southern part)	+ 05	+ 10	+ 50	+1 10	+1 25	+1 45	.....	.....	.....

4


1900
1890
1880
1870
1860
1850
1840
1830
1820
1810
MAINE
N.H,VT,MASS
R.I &CONN.
N.Y. N.J.& PA.
OHIO
INDIANA
ILLINOIS
MICH
WIS.
MINN.
IOWA
MO.
NEB.
KAN
COLO.



ON ACCOUNT OF SECULAR VARIATION.

CHARACTERISTICS OF SECULAR VARIATION.

This table and the diagrams develop a number of peculiar features, to which attention may profitably be called. In the first place, most of the irregularities in the curves do not appear to be persistent in different States, showing that they are in all probability due to defects of observation. The flattening of the curve in New England and in other Northeastern States, when contrasted with its course in other Northern States, is, however, very marked, and appears to indicate something more than defects of observation, probably a veritable change in the secular variation. In Ohio, Indiana, and Illinois is seen the change in curvature due to the approach of the zero point of the secular variation. This occurs in Ohio about 1810, in Indiana in 1820, and in Illinois about the same year, or perhaps 1830. In Michigan, on the other hand, which should show a depression in the early part of the century synchronous with that in Indiana, the increase in the reduction for secular variation goes on at a uniform rate.

Comparing the curves of the Northern with those of the Southern States, we see that those of the latter States are much flatter, showing a much smaller average rate of change, and this reduction in the rate of change becomes greatest in Arkansas and Texas, in which States the reduction on account of secular variation is comparatively small. The States of Mississippi, Louisiana, Texas, and Arkansas show also that the curve of secular variation is there apparently greatly flattened, the change of curvature commencing earlier and extending over a greater number of years than in the North, where all the indications are that it has a comparatively sharp summit.

To illustrate further the change that this curve of secular variation has undergone in different parts of the country, I have combined the curves by groups of States, all of the Northern States, including New England, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Nebraska, and Kansas in one group, Delaware, Maryland, District of Columbia, the Virginias, the Carolinas, Georgia, Florida, Alabama, Kentucky, Tennessee, and Missouri in a second group, and Mississippi, Louisiana, Arkansas, and Texas in a third group.

In combining them it became necessary to take account of the fact that the summit of the curve, or the point at which the secular variation changes sign, crossed different States at different dates, and therefore it was necessary to combine the curves of different States in such way as to bring the summits of the curves together. Thus the reduction for 1800 in New York, New Jersey, and Pennsylvania was combined with that for 1810 in Ohio, and with that for 1820 in Indiana and Michigan, and with that for 1830 in Illinois.

In this way the following curves were obtained:

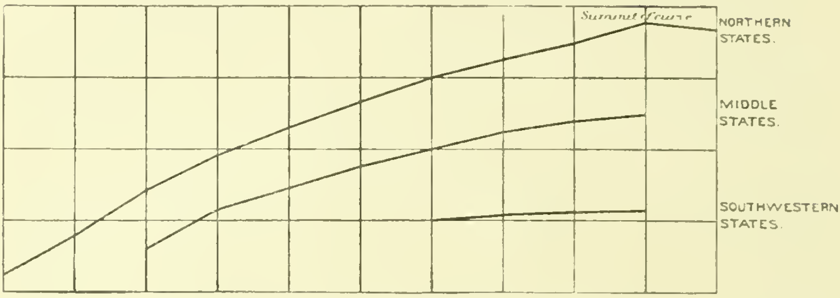


FIG. 2.—Diagrams of secular variation by sections of the country.

It will be noticed that the irregularities in the curves for individual States have been eliminated by their combination. The flattening of the curves in the more southern parts of the country is brought out very clearly by a comparison of these curves. In the last of the three this flattening has become extreme.

The following diagram shows in juxtaposition a portion of the declination curve at Paris, France, and the mean declination curve in the

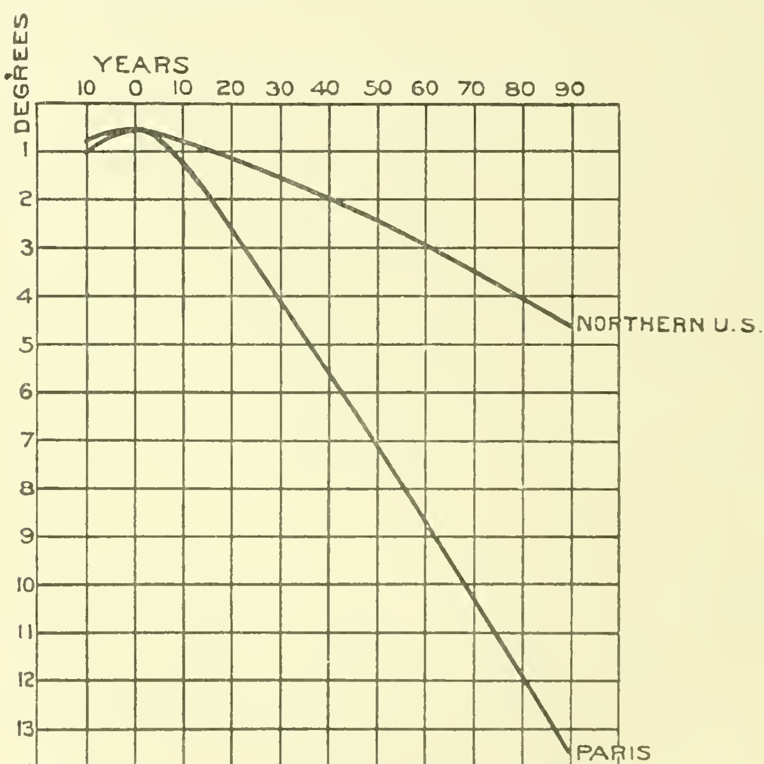


FIG. 3.—Diagrams of secular variation in northern United States and at Paris.

northern United States, both of them constructed upon the same scale. This diagram illustrates the rapid flattening of the curve as the latitude diminishes, Paris being in latitude 48° 57′, while the mid-latitude of this part of the United States is seven or eight degrees less.

Assuming that the secular change is due to an east-and-west movement of the supposed north magnetic pole, it would appear that the effect of this shifting of the pole diminishes southward, becoming, perhaps, zero at the magnetic equator.

THE COUNTY TABLE OF RESULTS.

The following table presents in what is believed to be a compact and convenient form for use the results of this compilation and discussion. These results are given in the form of the mean declination of each county in which observations for declination have been obtained. In counties in which no declinations have been obtained the declination of the year 1900 has been estimated from adjoining counties, as is indicated in the table. In addition to this, the declination is given at each town or city within the county at which such observations have been obtained. The mean of the county has been made up by taking the average year and the average declination of the observations. In the Land Office States the mean of only Land Office observations has been taken, those derived from other sources being, with few exceptions, omitted from this mean, and in case they could be located, given separately. In the non Land Office States all observations taken within the county have been included in the mean of the county. The reason for excluding from the county mean all observations excepting those of the General Land Office, in the Land Office States, is that the Land Office observations commonly differ widely in date from those derived from other sources, and consequently the mean year of the observations might not, and in many cases would not, correspond with the mean of the declinations.

In the case of many counties in the far Western States and Territories which are of large size, the mean declination is given for parts of such counties, cutting them up into from two to half a dozen parts for this purpose.

For convenience of reference, the States are arranged alphabetically, and the counties arranged alphabetically within the States. All the towns and cities for which declinations are given will be found under their respective counties, and in the few cases in which the city is not a part of any county it will be found in its alphabetic place among the counties.

The first column in the table gives the names of the counties, the second column the names of cities and towns included therein. The third column gives the year of observation, and in the case where the mean of several observations is presented the mean of the years of observation. The fourth column gives the observed declination or the means of the observed declinations. The fifth column gives the declination reduced to the epoch 1900, such reduction having been effected in accordance with the little table contained in the descriptive matter at the head of each State. The last column contains the authority, reference, and number of observations from which the mean result was obtained and other explanatory remarks.

The results for 1900 are given only to the nearest five minutes, and should be depended upon only to a quarter of a degree, since the numerous sources of error above enumerated may easily produce probable errors of that magnitude.

THE DECLINATION MAP.

The map of the United States accompanying this paper, showing the distribution of the lines of equal magnetic declination, was prepared by platting upon a large map of the United States, showing county lines and many other details, the mean results for declination in 1900 in all cases in which it had been obtained. In addition to these figures, the declinations at many towns were platted, especially in the Northeastern States and in the large counties of the West. Having platted these results, the lines were sketched freely upon the map, as nearly as possible in conformity to the figures. It goes without saying that in numerous cases, owing to the abundance and the conflicting nature of the data, all the data could not be satisfied by any possible adjustment of the lines, but it is believed that the best adjustment has been reached which could be obtained by this graphic method. The regions in which the data are the most conflicting are those in which, presumably, local attraction is great, as in northern Michigan and Wisconsin, and in the Southeastern States, where the data are both scanty and poor in quality.

ALABAMA.

Observations for magnetic declination in Alabama are derived in the main from the subdivision surveys of the General Land Office; a few come from county surveyors' returns and from the United States Coast and Geodetic Survey. The observations by the General Land Office bear dates ranging from 1832 to 1853. They appear to be of fair quality, although it is probable that considerable areas have been subdivided upon the same magnetic declination.

These observations have been reduced to the epoch 1900 by the application of corrections deduced from series of observations in this State, which are set forth in the following table:

Year.	Reduction.	Year.	Reduction.
1890	0 25	1850	2 30
1880	0 50	1840	2 55
1870	1 10	1830	3 20
1860	2 15		

The declination is east, and the above reductions are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Autauga		1842	6 30	3 40	Mean of 8 stations.
Baldwin		1841	6 35	3 40	Do.
	Fort Morgan	1847	7 04	4 25	C. & G. S.
Barbour		1832	6 30	3 15	Mean of 8 stations.
	Eufaula	1860	5 12	3 00	C. & G. S.
Bibb	Blocton	1895	3 30	3 15	County surveyor.
Blount		1839	5 40	2 40	Mean of 3 stations.
Bullock		1832	6 30	3 15	Mean of 6 stations.
Butler				3 45	Estimated.
Calhoun	Jacksonville	1895	2 45	2 30	County surveyor.
Chambers		1833	6 22	3 10	Mean of 18 stations.
Cherokee	Indian Mountain	1875	4 10	2 55	C. & G. S.
Chilton		1842	6 30	3 40	Mean of 3 stations.
Choctaw				5 00	Estimated.
Clarke				4 00	Do.
Clay		1832	5 25	2 10	Mean of 18 stations.
Cleburne				2 30	Estimated.
Coffee				3 20	Do.
Colbert	Tuscumbia	1896	4 43	4 30	County surveyor.
Conecuh		1839	5 45	2 45	Mean of 10 stations.
	Evergreen	1875	5 32	4 15	N. A. S.
Coosa		1832	6 30	3 15	Mean of 17 stations.
	Goodwater	1895	2 30	2 15	County surveyor.
Covington				3 30	Estimated.
Crenshaw				3 30	Do.
Cullman		1839	5 40	2 40	1 station.
Dale				3 15	Estimated.
Dallas		1844	6 47	4 00	Mean of 18 stations.
	Cahaba	1860	6 10	3 55	C. & G. S.
	Selma	1895	4 00	3 45	County surveyor.
Dekalb		1839	5 40	2 40	Mean of 3 stations.
Elmore		1838	6 30	3 30	Mean of 8 stations.
Escambia		1839	5 40	2 40	Do.
Etowah		1839	5 40	2 40	1 station.
Fayette				4 00	Estimated.
Franklin				4 15	Do.
Geneva				3 15	Do.
Greene		1838	7 06	4 05	Mean of 5 stations.
Hale		1842	6 30	3 40	Mean of 8 stations.
	Greensboro	1895	4 40	4 25	County surveyor.
Henry				3 00	Estimated.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Jackson				2 45	Estimated.
Jefferson	Birmingham	1875	4 26	3 10	N. A. S.
Lamar				4 30	Estimated.
Lauderdale	Florence	1881	4 28	3 40	C. & G. S.
Lawrence	Moulton	1895	2 30	2 15	County surveyor.
Lee		1832	6 30	3 15	Mean of 16 stations.
	Opelika	1875	4 30	3 15	N. A. S.
Limestone				3 30	Estimated.
Lowndes		1846	6 50	3 50	Mean of 4 stations.
Macon		1832	6 30	3 15	Mean of 8 stations.
	Tuskegee	1888	3 55	3 25	C. & G. S.
Madison	Madison	1875	5 12	3 55	N. A. S.
Marengo		1842	6 30	3 40	Mean of 2 stations.
	Shiloh	1895	4 15	4 00	County surveyor.
Marion				4 15	Estimated.
Marshall		1839	5 40	2 40	Mean of 10 stations.
Mobile		1846	7 00	4 20	Mean of 6 stations.
	Mobile	1895	4 45	4 30	County surveyor.
Monroe		1839	5 36	2 35	Mean of 7 stations.
Montgomery		1843	6 30	3 45	Mean of 20 stations.
	Montgomery	1856	5 18	2 55	C. & G. S.
Morgan		1853	5 17	2 50	Mean of 3 stations.
	Decatur	1881	5 10	4 25	C. & G. S.
Perry		1845	6 50	4 10	Mean of 2 stations.
	Marion	1895	4 15	4 00	County surveyor.
Pickens		1832	8 00	4 45	1 station.
Pike	Troy	1895	4 06	3 50	County surveyor.
Randolph		1831	5 28	2 20	Mean of 23 stations.
	West	1895	2 30	2 15	County surveyor.
Russell		1832	6 30	3 15	Mean of 24 stations.
St. Clair				2 45	Estimated.
Shelby				3 15	Do.
Sumter		1832	7 50	4 35	Mean of 8 stations.
	Coatopa	1873	5 50	4 25	County surveyor.
Talladega		1832	5 26	2 10	Mean of 6 stations.
Tallapoosa		1832	6 30	3 15	Mean of 20 stations.
Tuscaloosa	Tuscaloosa	1895	5 00	4 45	County surveyor.
Walker				3 30	Estimated.
Washington				4 30	Do.
Wilcox		1846	6 36	3 55	Mean of 9 stations.
Winston				3 30	Estimated.

ARIZONA.

Observations are derived almost entirely from the surveys of standard lines and township exteriors by the General Land Office, together with a few returns from county surveyors. They appear to be everywhere of excellent quality.

The line of no secular variation crossed Arizona about 1870, and these observations have been corrected in accordance therewith, using the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1860	0 50
1880	0 50	1850	0 30
1870	1 00		

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Apache	North	......	....	13 30	Estimated.
	Middle	1882	14 12	13 20	Mean of 94 stations.
	South	1882	13 45	12 55	Mean of 58 stations.
Cochise	Northeastern	1884	12 51	12 10	Mean of 17 stations.
	Southeastern	1884	12 38	12 00	Mean of 15 stations.
	Northwestern	1880	12 58	12 10	Mean of 17 stations.
	Southwestern	1885	12 20	11 40	Mean of 27 stations.
Coconino	Southern	1883	14 40	14 00	Mean of 58 stations.
	Northeastern	......	....	14 15	Estimated.
	Northwestern	......	....	14 45	Do.
Gila	Eastern	......	....	12 45	Do.
	Western	1881	14 15	13 25	Mean of 9 stations.
	Globe	1895	13 30	13 15	County surveyor.
Graham	Northeastern	1887	12 30	11 50	Mean of 2 stations.
	Southeastern	1883	12 30	11 50	Mean of 5 stations.
	Northwestern	1875	14 10	13 15	Mean of 2 stations.
	Southwestern	1880	13 24	12 35	Mean of 18 stations.
	Duncan	1895	12 10	12 00	County surveyor.
	Clifton	1895	12 17	12 05	Do.
	Solomonville	1895	12 25	12 15	Do.
	Safford	1895	12 30	12 20	Do.
	Camp Grant	1895	12 25	12 15	Do.
	Camp Thomas	1895	12 32	12 20	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900	Remarks.
			° ′	° ′	
Maricopa	Eastern	1876	13 40	12 45	Mean of 40 stations.
	Northwestern			13 15	Estimated.
	Southwestern	1882	13 29	12 40	Mean of 31 stations.
Mohave	Northern			15 00	Estimated.
	Middle	1876	15 00	14 05	Mean of 6 stations.
	Southern			13 45	Estimated.
Navajo	Northern			14 00	Do.
	Middle	1882	13 53	13 00	Mean of 78 stations.
	Southern	1883	13 58	13 10	Mean of 13 stations.
Pima	Northeastern	1870	13 17	12 15	Mean of 16 stations.
	Southeastern	1880	13 39	12 50	Mean of 38 stations.
	Central	1886	12 49	12 10	Mean of 26 stations.
Pinal	Eastern	1880	14 12	13 20	Mean of 19 stations.
	Western	1877	13 32	12 40	Mean of 42 stations
Yavapai	Eastern	1876	14 16	13 20	Mean of 21 stations.
	Northwestern	1880	14 09	13 20	Mean of 28 stations.
	Southwestern	1874	14 05	13 10	Mean of 17 stations.
Yuma	Lower Gila Valley.	1881	14 36	13 45	Mean of 27 stations.
	Colorado Valley.	1875	13 36	12 40	Mean of 11 stations.
	Yuma	1893	13 45	13 25	County surveyor.

ARKANSAS.

Observations for magnetic declination in Arkansas are derived from the subdivisional surveys of the General Land Office. the surveys of the northern and western boundaries of the State, and a few observations by the United States Coast and Geodetic Survey, Engineer Corps, National Academy of Sciences, and by county surveyors.

The observations for declination by the General Land Office, which form the great body of those collected, were made between the years 1816 and 1855, the earlier ones being, as a rule, in the eastern part of the State, and the later ones in the western part. The earlier of these results are manifestly considerably in error. The fifth principal meridian, the first line run, which passes north from the mouth of the Arkansas River in the eastern portion of the State, was run in the year 1816 on a variation of 8°. This declination was apparently correct at that time and place, but this declination of 8° was used almost exclusively for the next fifteen years in various portions of the State. I have therefore thrown out all observations taken prior to 1840. This leaves, however, an abundance of data, presumably of better quality.

The returns from the county surveyors, with two or three exceptions.

are evidently based, not upon observations on Polaris, but upon a rerunning of early land lines, since with few exceptions they give declinations which are too small. They agree, however, with the results of the Land Office surveys when corrected for secular variation.

Apparently the line of no secular change crossed Arkansas between the years 1830 and 1840, and the reductions for secular variation to 1900, derived from series observed in the State, are as follows:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1860	1 20
1880	1 15	1850	1 25
1870	1 15	1840	1 20

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Arkansas		1849	7 24	6 00	Mean of 12 stations.
Ashley		1842	8 13	6 50	Mean of 21 stations.
Baxter		1847	8 10	6 45	1 station.
Do		1845	8 53	7 30	Boundary survey.
Benton		1877	9 33	8 20	Do.
Boone		1846	7 56	6 30	Mean of 12 stations.
Bradley		1842	8 30	7 10	1 station.
Calhoun				6 30	Estimated.
Carroll		1845	8 00	6 35	Mean of 15 stations.
Chicot		1845	7 00	5 35	Mean of 2 stations.
Clark		1850	7 40	6 15	Mean of 8 stations.
Clay		1846	7 25	6 00	Mean of 13 stations.
Cleburne		1843	7 35	6 10	Mean of 12 stations.
Cleveland		1844	8 12	6 50	Mean of 3 stations.
Columbia		1857	7 37	6 20	Mean of 2 stations.
Conway		1870	8 15	7 00	Mean of 3 stations by C. & G. S.
Craighead		1849	7 00	5 35	Mean of 13 stations.
Crawford		1877	9 15	8 00	Boundary survey.
Crittenden		1845	7 40	6 05	Mean of 2 stations.
	Scanlons Landing	1878	6 57	5 40	U. S. Engin'r Corps.
Cross		1846	7 30	6 15	Mean of 8 stations.
Dallas		1853	7 20	5 55	1 station.
	Isaac Creek	1870	7 30	6 15	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Desha		1843	7 05	5 40	Mean of 4 stations.
Drew		1844	7 50	6 30	Do.
	Monticello	1895	6 57	6 40	County surveyor.
Faulkner		1847	7 48	6 25	Mean of 6 stations.
Franklin		1845	8 00	6 35	Do.
Fulton		1852	7 38	6 15	Do.
Do		1845	8 17	6 55	Boundary survey.
Garland		1845	8 20	6 55	Mean of 10 stations.
	Hot Springs	1895	7 26	7 05	County surveyor.
Grant		1848	7 40	6 15	Mean of 6 stations.
Greene		1855	7 25	6 00	Mean of 11 stations.
Hempstead		1838	8 00	6 40	Mean of 5 stations.
Hot Spring		1850	7 30	6 10	Mean of 9 stations.
Howard		1843	8 15	6 55	1 station.
Independence		1853	7 20	6 00	Mean of 13 stations.
Izard		1852	7 10	5 45	Mean of 4 stations.
Jackson		1840	7 25	6 05	Mean of 12 stations.
Jefferson		1850	8 40	7 15	Mean of 4 stations.
Johnson		1844	7 40	6 20	Mean of 9 stations.
Lafayette		1842	7 10	5 50	Mean of 4 stations.
Lawrence		1848	7 15	5 55	Mean of 12 stations.
Lee		1855	7 30	6 05	Mean of 2 stations.
Do		1879	6 25	5 10	U. S. Engin'r Corps.
Lincoln		1840	8 40	7 20	Mean of 7 stations.
Little River		1837	8 10	6 50	Mean of 3 stations.
Logan		1841	8 25	7 05	Mean of 8 stations.
	Roseville	1870	8 50	7 35	C. & G. S.
Lonoke		1854	7 10	5 50	Mean of 16 stations.
Madison		1841	7 50	6 30	Mean of 27 stations.
Marion		1840	7 43	6 25	Mean of 23 stations.
	Buffalo	1878	8 00	6 45	U. S. Engin'r Corps.
Miller		1842	7 47	6 25	Mean of 18 stations.
Mississippi		1844	7 48	6 30	Mean of 32 stations.
Monroe		1845	7 18	6 00	Mean of 9 stations.
Montgomery		1845	8 00	6 40	Mean of 20 stations.
Nevada	Prescott	1895	5 30	5 10	County surveyor.
Newton		1844	7 36	6 15	Mean of 27 stations.
Ouachita		1853	7 00	5 40	Mean of 2 stations.
	Camden	1895	5 15	5 00	County surveyor.
Perry		1843	8 00	6 40	Mean of 8 stations.
Phillips		1844	8 05	6 45	Mean of 5 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Pike		1842	7 56	6 35	Mean of 11 stations.
Poinsett		1848	7 35	6 15	Mean of 18 stations.
Polk		1844	8 17	7 00	Mean of 25 stations.
Do		1877	8 35	7 20	Boundary survey.
Pope		1843	7 40	6 20	Mean of 8 stations.
Do		1870	8 25	7 10	C. & G. S.
Prairie		1847	7 35	6 10	Mean of 20 stations.
Pulaski		1853	7 45	6 20	Mean of 12 stations.
	Little Rock	1875	8 11	6 55	N. A. S.
	Williams Landing	1870	7 15	6 00	C. & G. S.
Randolph		1852	7 20	6 00	Mean of 5 stations.
St. Francis		1849	7 22	6 00	Do.
Saline		1845	7 55	6 35	Mean of 6 stations.
Scott		1844	7 57	6 35	Mean of 25 stations.
Do		1877	8 42	7 35	Boundary survey.
Searey		1844	7 35	6 10	Mean of 12 stations.
Sebastian		1877	8 52	7 40	Boundary survey.
	Fort Smith	1878	8 50	7 35	U. S. Engin'r Corps.
	Evans Landing	1870	9 00	7 45	C. & G. S.
Sevier		1856	9 05	7 45	Mean of 4 stations.
Do		1877	8 25	7 10	Boundary survey.
Sharp		1853	7 30	6 05	Mean of 6 stations.
Stone		1844	7 30	6 10	Mean of 2 stations.
Union		1854	7 45	6 20	Mean of 4 stations.
Van Buren		1843	7 35	6 15	Mean of 14 stations.
Washington		1877	9 10	7 55	Boundary survey.
White		1851	7 10	5 45	Mean of 16 stations.
Woodruff		1843	7 40	6 20	Mean of 11 stations.
	Snapp	1895	5 54	5 40	County surveyor.
Yell		1839	8 06	6 45	Mean of 20 stations.
	Danville	1895	6 10	5 55	County surveyor.

CALIFORNIA.

The data for magnetic declination in California are derived in the main from the General Land Office, with a number of stations from the United States Coast and Geodetic Survey, and several returns from county surveyors. In addition to these there are reports from a few stations by the United States Geographical Surveys West of the One Hundredth Meridian, which are designated by the name "Wheeler" in the county table. The Land Office observations, which range from 1860 down to near the present date, are derived from the surveys of standard lines and township exteriors, and appear to be of excellent quality.

While there is a large body of data for the determination of the rate of secular change, its complexity renders its determination a somewhat difficult matter, since the zero of secular variation appears to have crossed the lower Colorado River about 1880, to have passed the one hundred and twentieth meridian in 1890, and to be off the Northwest coast in 1900. The observations have been corrected in accordance with this hypothesis, using the following table.

The column headed "Middle part" applies to the Sacramento and San Joaquin valleys and the coast from San Francisco Bay southward, across which area the zero of secular variation probably passed about 1890. It was derived from series observed in this area. The other columns are derived from this, the first on the assumption of the passage of the zero of secular variation about 1880, the last in 1900.

Year.	Reduction.		
	Southeastern part.	Middle part.	Western part.
	° ′	° ′	° ′
1890	−0 05	0 00	+0 05
1880	0 00	+0 05	0 10
1870	+0 05	0 10	0 50
1860	0 10	0 50	1 10
1850	0 50	1 10	1 25
1840	1 10	1 25	1 45
1830	1 45	1 45	....

The declination is east. Such of the above corrections as have the minus sign are to be subtracted; those having the plus sign, added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Alameda		1861	17 07	17 45	Mean of 3 stations.
Alpine		1877	16 45	16 50	1 station.
Amador		1873	16 15	16 20	Mean of 3 stations.
Butte		1868	17 00	17 25	Mean of 8 stations.
Calaveras		1872	16 20	16 35	Mean of 5 stations.
	Railroad Flat	1881	16 36	16 35	County surveyor.
Colusa		1881	16 43	16 45	Mean of 3 stations.
Contra Costa		1869	16 40	17 00	Mean of 7 stations.
	Monte Diablo	1881	16 43	16 40	C. & G. S.
Del Norte				19 20	Estimated.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Eldorado		1870	16 18	16 30	Mean of 8 stations.
	Lake Tahoe	1879	16 48	16 50	C. & G. S.
Fresno	Eastern	1878	15 34	15 40	Mean of 4 stations.
	Western	1868	16 12	16 30	Mean of 2 stations.
Glenn	Orland	1892	17 40	17 40	County surveyor.
	Willows	1894	17 40	17 40	Do.
Humboldt		1861	17 23	18 30	Mean of 5 stations.
	Eureka	1871	18 43	19 30	C. & G. S.
	Humboldt	1854	17 05	18 25	Do.
Inyo	Northern	1880	16 09	16 15	Mean of 5 stations.
	Southern	1877	15 15	15 35	Mean of 14 stations.
	Desert Springs	1871	15 30	15 40	Wheeler.
	Indian Wells	1875	15 13	15 25	Do.
	Saratoga Springs	1875	15 05	15 15	Do.
	Panamint Valley	1875	15 10	15 20	Do.
	Wild Rose Spring	1875	15 20	15 30	Do.
	Passmore	1875	14 54	15 05	Do.
	Furnace Creek	1875	15 42	15 50	Do.
	Cerro Gordo	1875	15 19	15 30	Do.
	Lone Pine	1875	15 20	15 30	Do.
	Independence	1871	15 34	16 55	Do.
Kern	Eastern	1880	15 02	15 10	Mean of 9 stations.
	Western	1882	15 40	15 45	Mean of 5 stations.
Kings	Hanford	1887	15 30	15 30	County surveyor.
Lake		1880	17 15	17 20	Mean of 2 stations.
Lassen		1869	17 24	17 45	Mean of 16 stations.
	Susanville	1877	18 21	18 25	C. & G. S.
Los Angeles		1883	14 40	14 40	Mean of 4 stations.
	Los Angeles	1893	14 25	14 25	County surveyor.
	San Pedro	1881	14 27	14 25	C. & G. S.
Madera				16 00	Estimated.
Marin		1863	15 52	16 30	Mean of 3 stations.
	Mount Tamalpais	1880	16 00	16 05	C. & G. S.
Mariposa		1875	15 40	15 45	Mean of 2 stations.
Mendocino	Northern	1892	18 03	18 10	Do.
	Southern	1874	17 06	17 35	Mean of 8 stations.
	Ukiah	1894	17 20	17 30	County surveyor.
	Point Arena	1889	17 13	17 20	C. & G. S.
Merced	Merced	1895	15 47	15 45	County surveyor.
Modoc		1872	17 22	17 35	Mean of 11 stations.
	Old Camp Bidwell.	1877	17 53	18 00	Wheeler.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Mono		1885	17 02	17 00	Mean of 10 stations.
	Bridgeport	1895	16 35	16 35	County surveyor.
Monterey		1882	15 49	15 55	Mean of 5 stations.
	Monterey	1881	15 55	16 00	C. & G. S.
Napa		1879	16 54	17 00	Mean of 5 stations.
	St. Helena	1895	16 55	16 55	County surveyor.
	Monticello	1880	17 13	17 20	C. & G. S.
Nevada		1868	17 07	17 30	Mean of 5 stations.
Orange		1880	14 00	14 05	Mean of 2 stations.
Placer		1871	16 06	16 20	Mean of 16 stations.
	Blue Canyon	1881	15 38	15 40	C. & G. S.
	Cisco	1877	17 10	17 20	Wheeler.
	Lake Tahoe	1876	15 51	15 55	Do.
Plumas		1868	17 06	17 20	Mean of 9 stations.
Riverside	Riverside	1896	14 30	14 30	County surveyor.
Sacramento		1880	16 00	16 00	Mean of 4 stations.
	Sacramento	1889	15 53	15 55	C. & G. S.
San Benito	Hollister	1895	16 03	16 05	County surveyor.
San Bernardino	Northeastern	1865	14 17	14 25	Mean of 4 stations.
	Southeastern	1882	14 46	14 50	Mean of 6 stations.
	Northwestern	1859	15 50	16 00	1 station.
	Southwestern	1865	14 00	14 10	Do.
San Diego	Eastern	1876	13 46	13 45	Do.
	Western	1868	13 23	13 30	Mean of 5 stations.
	San Diego	1881	13 27	13 25	C. & G. S.
	Fort Yuma	1876	13 45	13 50	Wheeler.
San Francisco	San Francisco	1886	16 40	16 50	C. & G. S.
San Joaquin				16 00	Estimated.
San Luis Obispo		1879	15 06	15 05	Mean of 6 stations.
	San Luis Obispo	1881	15 30	15 30	C. & G. S.
San Mateo		1865	15 45	16 10	1 station.
Santa Barbara		1884	14 45	14 45	Mean of 6 stations.
	Santa Barbara	1881	14 51	14 50	C. & G. S.
Santa Clara		1880	16 20	16 20	Mean of 20 stations.
	San Jose	1895	16 35	16 35	County surveyor.
	Mount Hamilton	1888	15 50	15 50	C. & G. S.
Santa Cruz				16 00	Estimated.
Shasta		1869	17 34	17 45	Mean of 7 stations.
Sierra		1867	17 05	17 25	Mean of 10 stations.
Siskiyou	Eastern	1887	18 50	18 50	Mean of 2 stations.
	Western	1875	19 36	19 40	1 station.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Siskiyou	Yreka	1894	19 34	19 35	County surveyor.
Solano		1875	17 00	17 05	Mean of 12 stations.
	Mare Island	1887	17 10	17 10	C. & G. S.
	Suisun	1850	15 40	16 50	
Sonoma		1860	16 22	17 10	Mean of 2 stations.
Stanislaus		1866	15 20	15 50	1 station.
Sutter		1874	15 25	15 30	Mean of 3 stations.
	Yuba	1894	15 15	15 15	County surveyor.
Tehama		1869	17 41	17 50	Mean of 5 stations.
Trinity		1873	18 15	18 45	Mean of 3 stations.
Tulare	Eastern	1873	11 35	14 45	1 station.
	Western			15 30	Estimated.
Tuolumne		1874	16 00	16 10	Mean of 7 stations.
Ventura		1876	15 04	15 10	Mean of 2 stations.
	San Buenaventura	1870	15 08	15 20	C. & G. S.
Yolo		1872	16 00	16 10	1 station.
Yuba		1879	17 06	17 10	Mean of 4 stations.
	Marysville	1889	16 42	16 40	C. & G. S.

COLORADO.

Observations in Colorado have been derived almost exclusively from the surveys of standard lines and township exteriors by the General Land Office. A few have been compiled from the Coast and Geodetic Survey, and a few have been received from county surveyors. The land-survey work is comparatively recent in date, the earliest observations having been taken in 1860, while most of them are subsequent to 1870.

The line of no secular variation crossed Colorado between 1860 and 1865, and these observations have been corrected accordingly by the use of the following table, derived from series observed in the State:

Year.	Reduction.	
	Eastern part.	Western part.
	° ′	° ′
1890	0 40	0 35
1880	1 10	1 00
1870	1 25	1 10
1860	1 40	1 10

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
Arapahoe	Eastern	1871	14 10	12 40	Mean of 14 stations.
	Middle	1862	14 30	12 45	Do.
	Western	1860	15 05	13 25	Mean of 11 stations.
	Denver	1888	14 06	13 25	C. & G. S.
Archuleta		1884	15 10	14 20	Mean of 7 stations.
Baca		1873	13 45	12 25	Mean of 3 stations.
Bent		1871	13 40	12 15	Mean of 5 stations.
	West Las Animas	1888	13 00	12 20	C. & G. S.
Boulder		1866	15 06	13 30	Mean of 10 stations.
Chaffee		1876	15 12	14 00	Mean of 4 stations.
Cheyenne		1870	13 50	12 25	Do.
Clear Creek		1867	15 02	13 30	Mean of 2 stations.
Conejos		1876	14 07	12 50	Mean of 5 stations.
Costilla		1871	14 11	12 45	Mean of 7 stations.
	San Luis	1895	13 44	13 00	County surveyor.
Custer		1871	14 21	13 00	Mean of 4 stations.
Delta		1891	14 40	14 10	Mean of 2 stations.
	Delta	1895	14 45	14 30	County surveyor.
Dolores		1885	14 20	13 30	Mean of 4 stations.
Douglas		1866	15 10	13 35	Mean of 6 stations.
Eagle		1890	14 51	14 15	Mean of 4 stations.
Elbert		1866	14 22	12 40	Mean of 7 stations.
El Paso		1869	14 57	13 20	Mean of 9 stations.
	Colorado Springs	1886	14 24	13 35	C. & G. S.
Fremont		1877	14 27	13 10	Mean of 7 stations.
Garfield	Eastern	1890	15 25	14 50	Mean of 4 stations.
	Western	1894	15 20	15 00	Mean of 2 stations.
Gilpin		1867	15 02	13 30	Do.
Grand		1879	15 03	14 10	Mean of 11 stations.
Gunnison		1882	14 44	13 45	Mean of 13 stations.
	Gunnison	1886	14 43	13 55	C. & G. S.
Hinsdale		1881	14 26	13 25	Mean of 4 stations.
Huerfano		1866	14 27	13 00	Mean of 6 stations.
Jefferson		1865	14 56	13 25	Mean of 5 stations.
Kiowa		1871	13 25	12 00	Mean of 2 stations
Kit Carson		1870	14 00	12 35	Do.
Lake		1875	15 40	14 20	1 station.
La Plata		1879	14 32	13 30	Mean of 8 stations.
Larimer	Eastern	1865	15 14	13 25	Mean of 9 stations.
	Western	1877	15 00	13 15	Mean of 2 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Las Animas	Eastern	1871	13 25	12 00	Mean of 4 stations.
	Western	1869	13 34	12 00	Mean of 7 stations.
	Trinidad	1888	13 47	13 00	C. & G. S.
Lincoln	Northern	1870	14 10	12 45	Mean of 2 stations.
	Southern	1870	14 12	12 45	Mean of 7 stations.
Logan		1870	14 46	13 20	Mean of 5 stations.
Mesa	Eastern	1892	15 05	14 35	Mean of 4 stations.
	Western			14 45	Estimated.
	Grand Junction	1895	14 48	14 30	County surveyor.
Mineral				13 50	Estimated.
Montezuma		1880	14 20	13 20	Mean of 3 stations.
	Mancos	1895	13 22	13 05	County surveyor
Montrose	Eastern	1884	14 25	13 40	Mean of 5 stations.
	Western	1888	14 24	13 45	Mean of 8 stations.
Morgan		1871	15 05	13 40	Mean of 12 stations.
	Fort Morgan	1895	14 45	14 30	County surveyor.
Otero		1871	13 56	12 30	Mean of 12 stations.
Ouray		1881	14 46	13 45	Mean of 3 stations.
	Ouray	1895	13 55	13 40	County surveyor.
Park		1872	15 36	14 15	Mean of 8 stations.
	Fairplay	1879	14 26	13 20	Wheeler.
	Alma	1895	13 50	13 35	County surveyor.
Phillips		1872	14 40	13 20	1 station.
Pitkin		1891	15 02	14 30	Mean of 3 stations.
	Aspen	1895	15 00	14 45	County surveyor.
Prowers				12 20	Mean of 3 stations.
Pueblo		1869	14 37	13 10	Mean of 12 stations.
	Pueblo	1888	13 13	12 20	C. & G. S.
Rio Blanco	Eastern	1883	15 10	14 20	Mean of 2 stations.
	Western			15 00	Estimated.
Rio Grande		1874	14 16	13 00	Mean of 9 stations.
	Del Norte	1895	13 59	13 40	County surveyor.
Routt	Eastern	1887	15 26	14 40	Mean of 17 stations.
	Western	1891	15 18	14 50	1 station.
	Toponas	1895	14 30	14 15	County surveyor.
Saguache		1876	14 10	12 55	Mean of 14 stations.
	Saguache	1873	14 24	13 05	Wheeler.
San Juan		1875	14 05	12 50	Mean of 2 stations.
San Miguel		1881	14 20	13 20	Mean of 4 stations.
Sedgwick		1880	14 20	13 10	Mean of 2 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Summit		1891	14 30	14 00	Mean of 2 stations.
Washington		1868	14 40	13 10	Mean of 11 stations.
Weld	Northeastern	1870	15 30	14 05	1 station.
	Northwestern	1864	15 10	13 35	Mean of 11 stations.
	Southwestern	1861	15 05	13 25	Mean of 13 stations.
	Greeley	1878	14 34	13 20	C. & G. S.
Yuma		1866	14 30	13 00	Mean of 6 stations.

CONNECTICUT.

The data for Connecticut are derived almost entirely from the compilation of the Coast and Geodetic Survey, most of the observations being accredited directly to that organization. Two only have been received from correspondence with city surveyors. These data bear date from 1810 down to the present time.

Wherever in the county table the mean of several stations is given for the county, it is understood to include the stations which are given afterward separately.

The line of no secular variation is supposed to have crossed Connecticut in 1790; consequently none of these observations, with the possible exception of the one at Pomfret, are affected by the change in secular variation. They have been reduced to the epoch 1900 by the application of reductions derived from the series observed in western New England.

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 20	1840	3 40
1880	0 45	1830	4 40
1870	1 25	1820	5 20
1860	2 05	1810	5 50
1850	2 55		

The declination is west, and the reductions for secular variation are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Fairfield				10 05	Mean of 8 stations.
	Stamford	1844	6 24	9 45	C. & G. S.
	Norwalk	1844	6 50	10 10	Do.
	Black Rock	1845	6 53	10 10	Do.
	Bridgeport	1845	6 20	9 40	Do.
Hartford				10 15	Mean of 4 stations.
	Hartford	1879	8 34	9 20	C. & G. S.
Litchfield				10 50	1 station.
Middlesex				10 10	Mean of 2 stations.
	Saybrook	1845	6 50	10 10	C. & G. S.
	Middletown	1895	10 00	10 10	City surveyor.
New Haven				10 00	Mean of 10 stations.
	Milford	1845	6 38	9 55	C. & G. S.
	New Haven	1885	9 00	9 35	Yale College.
New London				11 00	Mean of 3 stations.
Tolland				10 00	Do.
	Hebron	1835	6 00	9 10	Silliman's Journal.
Windham	Pomfret	1810	5 08	11 00	Do.
	Putnam	1866	9 30	11 10	City surveyor.

DELAWARE.

Observations for magnetic declination are derived almost entirely from the United States Coast and Geodetic Survey, their date ranging from 1842 to 1885.

They have been reduced to the epoch 1900 by the application of the following table of reductions, derived from series of observations taken in Delaware, Maryland, District of Columbia, Virginia, and West Virginia.

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1840	3 30
1880	1 00	1830	4 00
1870	1 55	1820	4 10
1860	2 25	1810	4 20
1850	3 00		

The declination is west and the above corrections are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Kent	Bombay Hook	1847	3 19	6 30	C. & G. S.
Newcastle				6 10	Mean of 4 stations.
	Wilmington	1875	3 45	5 10	C. & G. S.
	Delaware City	1842	3 30	6 55	Trans. Royal Soc.
Sussex				5 45	Mean of 4 stations.
	Dagsboro	1856	2 40	5 25	C. & G. S.
	Cape Henlopen	1885	5 00	5 45	Do.
	Pilottown	1846	2 43	5 55	Do.
	Lewes Landing	1846	2 45	5 55	Do.

DISTRICT OF COLUMBIA.

In the District of Columbia there is presented the mean of six stations scattered over its area, with a mean date of 1875, these stations having been compiled from the work of the United States Coast and Geodetic Survey.

Upon many of the mileposts marking the boundaries of the District of Columbia, as it was run in the early part of the century, the declination at that date, as observed, has been marked. These results, however, are not presented, as they are of so early a date.

The table of reductions for the District of Columbia is similar to that above presented for Maryland, and was derived from a series of observations made in Delaware, Maryland, District of Columbia, Virginia, and West Virginia.

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1840	3 30
1880	1 00	1830	4 00
1870	1 55	1820	4 10
1860	2 25	1810	4 20
1850	3 00		

The declination is west, and the above corrections are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
District of Columbia.		1875	3 10	4 10	C. & G. S. Mean of 6 stations.

FLORIDA.

Observations for magnetic declination in Florida are derived mainly from the subdivision surveys of the General Land Office, with a few from county surveyors and the United States Coast and Geodetic Survey. The work of the Land Office has been done in this State since the year 1825. The observations appear to be of fair quality, showing accordance with observations from other sources at more recent dates, when reduced.

The observations have been reduced to the epoch 1900 by the application of corrections derived from series of observations in the State, as set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 25	1860	2 05
1880	0 50	1850	2 35
1870	1 30	1840	3 00

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Alachua		1835	5 18	2 05	Mean of 8 stations.
	Gainesville	1895	2 35	2 20	County surveyor.
Baker		1837	5 52	2 45	Mean of 4 stations.
Bradford		1850	5 30	2 55	Mean of 5 stations.
Brevard		1870	3 00	1 30	Mean of 12 stations.
	Eau Gallie	1880	2 00	1 10	C. & G. S.
	Titusville	1879	2 08	1 15	Do.
	Georgiana	1895	1 32	1 20	County surveyor.
Calhoun		1881	4 55	4 05	Mean of 2 stations.
Citrus		1855	4 06	1 45	Mean of 4 stations.
	Inverness	1894	2 35	2 20	County surveyor.
Clay				2 00	Estimated.
Columbia		1881	3 00	2 10	1 station.
Dade		1870	3 20	1 50	Mean of 5 stations.
De Soto		1850	4 18	1 40	Mean of 3 stations.
Duval		1881	2 20	1 30	Do.
	Jacksonville	1880	2 20	1 30	C. & G. S.
	Baldwin	1887	2 23	1 50	Do.
Escambia	Pensacola	1890	4 55	4 30	Do.
Franklin	Apalachicola	1860	6 12	4 05	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Gadsden				3 00	Estimated.
Hamilton		1891	3 10	2 45	Mean of 2 stations.
	Jasper	1895	2 38	2 25	County surveyor.
Hernando		1843	4 50	1 55	Mean of 9 stations.
Hillsboro		1845	4 35	1 50	Mean of 10 stations.
	Tampa	1887	3 02	2 30	C. & G. S.
Holmes				3 20	Estimated.
Jackson				3 10	Do.
Jefferson		1825	6 10	2 50	1 station.
Lafayette		1831	6 10	2 55	Do.
Lake		1843	4 20	1 30	Mean of 5 stations.
	Puntarasa	1866	4 00	2 15	C. & G. S.
Lee				1 45	Estimated.
Leon	Tallahassee	1875	3 42	2 30	N. A. S.
Levy		1863	4 08	2 15	Mean of 4 stations.
	Cedar Keys	1887	3 22	2 50	C. & G. S.
Liberty		1895	3 30	3 15	1 station.
Madison		1866	4 05	2 25	Mean of 3 stations.
	Madison	1895	2 50	2 35	County surveyor.
Manatee		1843	4 45	1 50	1 station.
Marion		1842	4 38	1 45	Mean of 14 stations.
	Ocala	1890	2 26	2 00	County surveyor.
Monroe		1885	3 20	2 45	Mean of 6 stations.
	Key West	1887	3 20	2 50	C. & G. S.
Nassau	Fernandina	1879	2 30	1 35	Do.
Orange		1865	3 43	2 00	Mean of 9 stations.
	Orlando	1893	2 27	2 10	County surveyor.
Osceola		1858	3 45	1 35	Mean of 4 stations.
	Kissimmee	1891	2 30	2 05	County surveyor.
Pasco		1846	4 22	1 45	Mean of 6 stations.
Polk		1850	4 40	2 05	Mean of 9 stations.
	Bartow	1895	1 54	1 40	County surveyor.
Putnam		1834	5 28	2 20	Mean of 2 stations.
St. Johns	St. Augustine	1880	2 42	1 50	C. & G. S.
Santa Rosa				3 45	Estimated.
Sumter		1845	4 30	1 45	Mean of 17 stations.
Suwannee		1863	4 15	2 20	Mean of 2 stations.
	Live Oak	1895	2 30	2 15	County surveyor.
Taylor				2 40	Estimated.
Volusia		1850	4 10	1 35	Mean of 8 stations.
	Enterprise	1880	2 45	1 55	C. & G. S.
	Daytona	1876	3 15	2 10	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Wakulla		1881	4 05	3 15	Mean of 2 stations.
	St. Marks	1875	4 30	3 20	N. A. S.
Walton				3 30	Estimated.
Washington		1881	4 50	4 00	1 station.

GEORGIA.

Declination data in Georgia are scanty, only about half the counties of the State being represented. Observations are derived from various sources—returns from county surveyors, Geological Survey of Georgia, United States Coast and Geodetic Survey, and the National Academy of Sciences.

These observations are of date ranging back as far as 1837, those of that year, 1838, and 1839 coming from the Geological Survey of the State. The others are of much more recent date, most of those of the Coast and Geodetic Survey being taken between 1870 and 1890, while the county surveyors' returns bear date mainly 1895.

These observations have been reduced to the epoch 1900 by means of corrections derived from series of observations taken in this State and the two Carolinas. They are set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 35	1840	3 15
1880	1 05	1830	3 30
1870	1 50	1820	3 45
1860	2 20	1810	4 05
1850	2 45		

The declination is east, and these corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Appling				1 30	Estimated.
Baker	Mimsville	1895	1 30	1 15	County surveyor.
Baldwin	Milledgeville	1887	3 37	2 55	C. & G. S.
Banks	Homer	1895	1 30	1 15	County surveyor.
Bartow	Pinelog	1874	4 00	2 30	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Bartow	Stilesboro	1895	2 30	2 15	County surveyor.
Berrien				1 50	Estimated.
Bibb	Macon	1888	2 30	1 50	C. & G. S.
Brooks				2 00	Estimated.
Bryan	Bryan	1838	5 05	1 45	Ga. Geol. Survey.
Bulloch				1 15	Estimated.
Burke	Waynesboro	1837	5 04	1 45	Ga. Geol. Survey.
Butts	Flovilla	1895	2 00	1 45	County surveyor.
Calhoun				2 00	Estimated.
Camden	Owens Ferry	1895	1 15	1 00	County surveyor.
Campbell		1895	1 30	1 15	Do.
Carroll				2 15	Estimated.
Catoosa				2 00	Do.
Charlton				1 45	Do.
Chatham	Skiddaway	1856	3 25	0 55	C. & G. S.
	Savannah	1886	1 31	0 45	Do.
Chattahoochee				2 45	Estimated.
Chattooga				2 15	Do.
Cherokee	Cumming	1873	3 13	1 35	C. & G. S.
Clarke	Athens	1896	1 42	1 30	County surveyor.
Clay	Fort Gaines	1839	5 30	2 15	Ga. Geol. Survey.
Clayton		1893	2 00	1 35	County surveyor.
Clinch		1895	1 30	1 15	Do.
	Lawton	1880	2 26	1 20	C. & G. S.
Cobb	Kennesaw	1873	4 43	3 05	Do.
Coffee				1 40	Estimated.
Colquitt		1895	1 45	1 30	County surveyor
Columbia	Appling	1837	5 00	1 40	Ga. Geol. Survey.
Coweta				2 10	Estimated.
Crawford	Knoxville	1895	2 15	2 00	County surveyor.
Dade				2 15	Estimated.
Dawson				1 45	Do.
Decatur	Bainbridge	1839	5 30	2 15	Ga. Geol. Survey.
Dekalb				2 00	Estimated.
Dodge				1 30	Do.
Dooly		1895	1 45	1 30	County surveyor.
Dougherty				2 00	Estimated.
Douglas				2 10	Do.
Early				3 00	Do.
Echols				2 00	Do.
Effingham	Oak Level	1837	5 05	1 45	Ga. Geol. Survey.
	Springfield	1837	5 05	1 45	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Effingham	Ashville	1837	5 05	1 45	Ga. Geol. Survey.
	Cottage Green	1837	5 05	1 45	Do.
Elbert	Elberton	1837	4 33	0 15	Do.
	Thornville	1837	4 33	0 15	Do.
Emanuel	Swainsboro	1838	5 04	1 45	Do.
	Birdsville	1837	5 00	1 40	Do.
Fannin	Morganton	1895	2 30	2 10	County surveyor.
Fayette	Fayetteville	1896	3 30	3 20	Do.
Floyd	Lavender	1874	4 00	2 30	C. & G. S.
Forsyth	Sawnee	1873	2 55	1 20	Do.
Franklin	Carnesville	1837	5 00	1 40	Ga. Geol. Survey.
Fulton	Middle Base	1873	3 35	2 00	C. & G. S.
Gilmer		1896	2 00	1 50	County surveyor.
Glascock				1 15	Estimated.
Glynn	Brunswick	1887	1 49	1 05	C. & G. S.
Gordon				2 00	Estimated.
Greene				1 30	Do.
Gwinnett	Lawrenceville	1874	3 25	1 50	C. & G. S.
Habersham	Currahee	1874	2 48	1 15	Do.
	Toccoa Falls	1837	5 00	1 40	Ga. Geol. Survey.
Hall	Skitt	1874	2 36	1 00	C. & G. S.
Hancock				1 30	Estimated.
Haralson				2 20	Do.
Harris				2 30	Do.
Hart				1 00	Do.
Heard				2 15	Do.
Henry				1 50	Do.
Houston		1895	2 00	1 45	County surveyor.
Irwin				1 45	Estimated.
Jackson				1 30	Do.
Jasper				1 40	Do.
Jefferson				1 15	Do.
Johnson		1895	3 00	2 45	County surveyor.
Jones		1885	2 30	1 40	Do.
Laurens				1 30	Estimated.
Lee				2 00	Do.
Liberty	Liberty	1838	5 05	1 45	Ga. Geol. Survey.
Lincoln	Lincolnton	1837	5 09	1 50	Do.
	Goshen	1837	5 09	1 50	Do.
Lowndes				2 00	Estimated.
Lumpkin	Grassy	1874	3 36	2 00	C. & G. S.
McDuffie				1 00	Estimated.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
McIntosh	Darien	1838	5 05	1 45	Ga. Geol. Survey.
Macon				1 50	Estimated.
Madison				1 00	Do.
Marion				2 00	Do.
Meriwether				2 00	Do.
Miller				2 45	Do.
Milton				2 00	Do.
Mitchell				2 00	Do.
Monroe		1895	1 15	1 00	County surveyor.
Montgomery				1 30	Estimated.
Morgan	Madison	1838	4 30	1 10	Ga. Geol. Snrvey.
Murray				2 00	Estimated.
Muscogee	Columbus	1839	5 30	2 15	Ga. Geol. Survey.
	do	1895	2 30	2 15	County surveyor.
Newton				1 45	Estimated.
Oconee				1 30	Do.
Oglethorpe				1 15	Do.
Paulding				2 15	Do.
Pickens				1 45	Do.
Pierce				1 30	Do.
Pike				2 00	Do.
Polk	Carnes	1873	4 05	2 30	C. & G. S.
Pulaski				1 30	Estimated.
Putnam	Eatonton	1838	4 32	1 15	Ga. Geol. Survey.
Quitman				3 00	Estimated.
Rabun				0 30	Do.
Randolph	Cuthbert	1839	5 30	2 15	Ga. Geol. Survey.
Richmond	Augusta	1837	5 04	1 45	Do.
Rockdale				1 45	Estimated.
Schley				2 00	Do.
Screven	Wendover	1837	4 55	1 35	Ga. Geol. Survey.
	Millen	1875	2 37	1 10	N. A. S.
	Black Creek	1837	5 04	1 45	Ga. Geol. Survey.
	Jacksonboro	1837	4 55	1 35	Do.
	Mill Haven	1837	5 04	1 45	Do.
Spalding	Griffin	1895	1 36	1 20	County surveyor.
Stewart	Lumpkin	1839	5 27	2 10	Ga. Geol. Survey.
Sumter				2 00	Estimated.
Talbot		1895	2 00	1 45	County surveyor.
Taliaferro				1 20	Estimated.
Tattnall	Baird Creek	1838	5 23	2 05	Ga. Geol. Survey.
Taylor	Butler	1872	2 43	1 00	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Telfair	Lumber	1875	3 11	1 40	N. A. S.
Terrell				2 15	Estimated.
Thomas				2 00	Do.
Towns				0 30	Do.
Troup	Lagrange	1895	2 30	2 15	County surveyor.
Twiggs				1 30	Estimated.
Union				1 00	Do.
Upson				2 00	Do.
Walker	Johns Mountain	1875	3 57	2 30	C. & G. S.
	Chickamauga	1893	2 02	1 35	County Surveyor.
Walton		1895	2 00	1 45	Do.
	Monroe	1838	5 10	1 50	Ga. Geol. Survey.
Ware	Waycross	1887	2 00	1 20	C. & G. S.
Warren				1 15	Estimated.
Washington	Sandersville	1838	5 27	2 10	Ga. Geol. Survey.
Wayne	Jesup	1887	1 45	1 00	C. & G. S.
Webster				2 15	Estimated.
White	Cleveland	1895	1 15	1 00	County surveyor.
Whitfield				2 00	Estimated.
Wilcox				1 45	Do.
Wilkes				1 00	Do.
Wilkinson				1 30	Do.
Worth				1 50	Do.

IDAHO.

Observations in Idaho are almost entirely from the General Land Office, with a few from county surveyors. The Land Office observations are of recent date, all having been taken within the last fifteen years, and are apparently of excellent quality.

Data for the determination of the secular change are scanty and of little value, mainly owing to the shortness of the period of time over which they extend. All indications, however, go to show that the line of no secular variation crossed the State between the years 1875 and 1885, and the data have been reduced under that supposition in accordance with the following table of reductions:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 20	1870	0 20
1880	0 30	1860	0 00

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Ada		1885	18 47	18 20	Mean of 20 stations.
	Boise	1895	18 45	18 35	County surveyor.
Bannock	Eastern	1880	17 45	17 15	Mean of 14 stations.
	Western	1890	17 40	17 20	Mean of 10 stations.
Bear Lake		1879	17 58	17 25	Mean of 6 stations.
Bingham	Eastern	1890	18 13	17 55	Mean of 4 stations.
	Western	1892	17 46	17 30	Mean of 6 stations.
Blaine	Eastern	1891	19 10	18 50	Mean of 12 stations.
	Western	1885	18 35	18 05	Mean of 3 stations.
Boise	Northern	1890	19 30	19 10	Mean of 5 stations.
	Southern	1885	19 03	18 30	Mean of 18 stations.
Canyon		1880	18 30	18 00	Mean of 4 stations.
	Caldwell	1893	19 00	18 50	County surveyor.
Cassia	Eastern	1881	17 48	17 20	Mean of 14 stations.
	Western	1889	17 48	17 25	Mean of 18 stations.
Custer	Eastern	1891	19 03	18 45	Mean of 29 stations.
	Western	1893	19 00	18 45	1 station.
Elmore	Northern	1874	18 45	18 20	Do.
	Southern	1887	18 58	18 30	Mean of 9 stations.
Fremont	Eastern	1891	18 15	18 00	Mean of 18 stations.
	Western	1877	18 30	18 05	1 station.
Idaho	Northeastern	1890	20 50	20 30	Mean of 4 stations.
	Southeastern			20 00	Estimated.
	Western	1884	20 42	20 15	Mean of 9 stations.
Kootenai	Northern	1893	22 15	22 00	Mean of 4 stations.
	Southern	1889	21 30	21 10	Mean of 22 stations.
Latah		1887	21 07	20 40	Mean of 8 stations.
	Moscow	1893	21 30	21 15	County surveyor.
Lemhi	Southeastern	1892	19 10	19 00	Mean of 3 stations.
	Northwestern	1889	19 30	19 10	Mean of 7 stations.
Lincoln	Eastern	1888	17 55	17 35	Mean of 15 stations.
	Western	1880	18 42	18 10	Mean of 10 stations.
Nez Perces		1885	20 52	20 20	Mean of 23 stations.
	Lewiston	1881	21 26	20 50	C. & G. S.
Oneida	Eastern	1872	18 00	17 40	Mean of 3 stations.
	Northwestern	1878	17 52	17 25	Do.
	Southwestern	1873	17 55	17 30	Do.
	Malade	1877	17 45	17 20	Wheeler.
Owyhee	Eastern	1877	18 27	18 00	Mean of 10 stations.
	Northwestern	1882	18 47	18 15	Mean of 12 stations.
	Southwestern	1879	18 48	18 15	Mean of 7 stations.
Shoshone	Northern	1891	21 30	21 10	Mean of 3 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Shoshone.......	Southern........	1892	21 12	21 00	Mean of 5 stations.
	Murray	1894	21 20	21 10	County surveyor.
	Wallace..........	1894	21 50	21 40	Do.
Washington	Northern.........	1891	19 07	18 50	Mean of 4 stations.
	Southern.........	1876	18 53	18 25	Mean of 10 stations.

ILLINOIS.

The results in Illinois are derived mainly from the subdivision surveys of the General Land Office, together with a few from the United States Lake Survey, United States Coast and Geodetic Survey, and a number of returns from county surveyors. The Land Office observations were taken between the years 1800 and 1850, and appear to be of fair quality.

The line of no secular variation apparently crossed Illinois between the years 1825 and 1830, and consequently a part of these Land Office observations are, in the reduction to 1900, complicated with the change in secular variation. The results for the reduction of observations taken at these early dates to the epoch 1900, as derived from series of observations taken in the State, have been adopted, and applied as shown in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890................	0 40	1850................	2 45
1880................	1 20	1840................	2 45
1870................	2 00	1830................	3 35
1860................	2 30	1820................	3 35

The declination is east, and the corrections for secular variation are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adams	....	......	....	5 30	Estimated.
Alexander......	Cairo	1877	6 00	4 30	C. & G. S.
Bond............	Greenville........	1895	5 20	5 00	County surveyor.
Boone..........	....	......	....	4 00	Estimated.
Brown	....	......	....	5 20	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Bureau		1827	8 11	4 40	Mean of 24 stations.
	Tiskilwa	1893	4 48	4 20	County surveyor.
Calhoun				5 45	Estimated.
Carroll				5 30	Do.
Cass	Virginia	1894	5 09	4 45	Mean of 4 results by county surveyor.
	Beardstown	1880	6 43	5 25	Nipher.
Champaign		1822	7 48	4 15	Mean of 32 stations.
Christian				4 45	Estimated.
Clark				4 00	Do.
Clay		1817	7 50	4 15	Mean of 6 stations.
Clinton				4 45	Estimated.
Coles		1821	8 30	4 55	Mean of 11 stations.
Cook		1829	7 19	3 45	Mean of 34 stations.
	Chicago	1888	4 07	3 20	C. & G. S.
	Willow Springs	1879	5 11	3 50	U. S. Lake Survey.
	Mount Forest	1876	5 00	3 20	Do.
	Winnetka	1873	5 00	3 10	Do.
Crawford		1828	7 30	3 55	Mean of 5 stations.
	Bellair	1879	5 08	3 50	U. S. Lake Survey.
Cumberland		1820	8 26	4 50	Mean of 11 stations.
Dekalb		1841	7 12	4 30	Mean of 3 stations.
Dewitt	Clinton	1892	4 45	4 15	County surveyor.
Douglas		1825	8 03	4 30	Mean of 16 stations.
Dupage		1834	7 17	4 05	Mean of 6 stations.
Edgar		1821	8 20	4 45	Mean of 15 stations.
	Palermo	1879	5 12	3 50	U. S. Lake Survey.
Edwards		1819	7 50	4 15	Mean of 2 stations.
Effingham		1820	7 50	4 15	Mean of 3 stations.
	Effingham	1850	6 45	4 00	County surveyor.
Fayette		1823	8 00	4 25	Mean of 2 stations.
	Vandalia	1895	4 45	4 25	County surveyor.
Ford		1831	7 52	4 20	Mean of 12 stations.
Franklin				4 30	Estimated.
Fulton				5 15	Do.
Gallatin		1895	4 30	4 10	County surveyor.
Greene		1895	5 15	4 55	Do.
Grundy		1821	8 06	4 30	Mean of 15 stations.
	Morris	1892	5 32	5 00	County surveyor.
Hamilton				4 30	Estimated.
Hancock		1895	5 32	5 15	County surveyor.
Hardin		1895	4 10	3 50	Do.
Henderson				5 45	Estimated.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Henry				5 15	Estimated.
Iroquois		1824	7 53	4 20	Mean of 34 stations.
Jackson				4 45	Estimated.
Jasper		1820	8 03	4 30	Mean of 21 stations.
Jefferson		1895	4 00	3 40	County surveyor.
Jersey				5 30	Estimated.
Jo Daviess	Galena	1876	9 08	7 35	U. S. Lake Survey.
	Sherwood	1839	9 00	6 10	Locke's Rep. Min. Lands.
	Dunleith	1856	9 00	6 25	K. K. A. S. Vienna, 1858.
Johnson	Vienna	1885	4 40	3 40	
Kane		1840	6 02	3 15	Mean of 10 stations.
Kankakee		1833	7 18	4 00	Mean of 17 stations.
Kendall		1833	8 06	4 45	Mean of 6 stations.
Knox	Galesburg	1895	5 25	5 05	County surveyor.
Lake		1840	5 56	3 10	Mean of 13 stations.
	Waukegan	1873	5 11	3 20	U. S. Lake Survey.
Lasalle		1822	8 06	4 30	Mean of 26 stations.
Lawrence		1805	6 10	3 30	Mean of 5 stations.
Lee		1843	7 38	4 50	Mean of 6 stations.
Livingston		1833	7 31	4 10	Mean of 8 stations.
Logan	Lincoln	1895	5 40	5 20	County surveyor.
McDonough				5 30	Estimated.
McHenry		1839	6 14	3 20	Mean of 12 stations.
	Woodstock	1894	3 40	3 10	County surveyor.
McLean		1824	8 00	4 25	Mean of 4 stations.
	Bloomington	1896	3 15	3 00	County surveyor.
Macon	Macon	1872	5 22	3 30	N. A. S.
Macoupin				5 00	Estimated.
Madison	Collinsville	1880	6 30	5 10	Nipher.
	Highland	1872	6 34	4 45	N. A. S.
	Alton	1840	7 45	5 00	Silliman's Journal.
Marion				4 30	Estimated.
Marshall		1828	8 05	4 30	Mean of 17 stations.
	Wenona	1872	6 06	4 15	N. A. S.
Mason	Havana	1892	4 47	4 15	County surveyor.
Massac				4 15	Estimated.
Menard		1895	4 50	4 30	County surveyor.
Mercer	Aledo	1895	5 25	5 05	Do.
Monroe	Waterloo	1895	5 05	4 45	Do.
Montgomery		1823	8 00	4 25	1 station.
Morgan	Jacksonville			5 45	Mean of 2 results.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Moultrie				4 30	Estimated.
Ogle				4 45	Do.
Peoria		1830	8 12	4 40	Mean of 20 stations.
Perry				4 45	Estimated.
Piatt				4 30	Do.
Pike	Barry	1895	5 00	4 40	County surveyor.
Pope	Golconda	1872	6 06	4 20	N. A. S.
Pulaski	America	1896	4 45	4 30	County surveyor.
	Mound City	1865	7 32	5 20	C. & G. S.
Putnam		1826	8 11	4 35	Mean of 10 stations.
	Hennepin	1895	4 57	4 40	County surveyor.
Randolph	Chester	1895	4 48	4 30	Do.
	Kaskaskia	1809	7 20	4 35	C. & G. S.
Richland		1821	7 40	4 05	Mean of 10 stations.
	Olney	1895	4 00	3 40	County surveyor.
Rock Island	Rock Island	1878	6 58	5 30	U. S. Lake Survey.
St. Clair	Belleville	1895	5 20	5 00	County surveyor.
	New Athens	1880	5 49	4 30	Nipher.
	Cahokia	1810	8 25	5 45	Silliman's Journal.
Saline				4 15	Estimated.
Sangamon	Springfield	1878	5 50	4 20	C. & G. S.
Schuyler	Rushville	1895	5 15	5 00	County surveyor.
Scott	Winchester	1892	6 12	5 40	Do.
Shelby				4 30	Estimated.
Stark		1820	8 05	4 30	Mean of 7 stations.
Stephenson		1895	6 00	5 40	County surveyor.
Tazewell		1824	8 00	4 25	Mean of 5 stations.
Union				4 30	Estimated.
Vermilion		1821	8 15	4 40	Mean of 38 stations.
	Pilot Grove	1879	4 30	3 05	U. S. Lake Survey.
	Danville	1895	4 00	3 40	County surveyor.
Wabash				3 30	Estimated.
Warren	Little York	1895	5 56	5 40	County surveyor.
Washington	Nashville	1880	6 11	4 55	Do.
Wayne		1818	7 51	4 20	Mean of 5 stations.
White				4 15	Estimated.
Whiteside		1843	7 26	4 40	Mean of 3 stations.
	Fulton	1844	8 15	5 30	C. & G. S.
Will		1825	7 47	4 10	Mean of 16 stations.
Williamson				4 30	Estimated.
Winnebago	Rockford			3 30	Mean of 2 results.
Woodford		1826	7 57	4 20	Mean of 9 stations.

INDIANA.

The declination data in Indiana consist in the main of observations from the subdivisional surveys of the General Land Office, together with a few returns from county surveyors and a few stations by the United States Coast and Geodetic Survey. The land surveys were made in this State between the years 1800 and 1850, and as the line of no secular variation crossed the State about 1820, the declination observations made in connection with the land surveys are greatly complicated with the change in declination. Corrections have been applied to reduce these observations to the epoch 1900 in accordance with the following table, derived from series observed within the State:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1840	3 00
1880	1 20	1830	3 20
1870	2 10	1820	4 10
1860	2 25	1810	3 45
1850	2 40	1800	3 20

The declinations are east, and the above reductions on account of secular variation are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adams		1822	5 42	1 40	Mean of 3 stations.
Allen		1832	5 26	2 10	Mean of 15 stations.
	Fort Wayne	1874	2 30	0 40	N. A. S.
Bartholomew		1820	6 08	1 55	Mean of 7 stations.
Benton		1832	6 23	3 10	Mean of 13 stations.
Blackford		1823	6 20	2 25	Mean of 5 stations.
	Hartford	1895	2 31	2 15	County surveyor.
Boone		1824	5 55	2 15	Mean of 6 stations.
Brown		1820	6 45	2 35	Mean of 5 stations.
Carroll		1829	5 33	2 15	Mean of 8 stations.
Cass		1830	5 42	2 20	Mean of 10 stations.
	Logansport	1836	5 35	2 25	Silliman's Journal.
Clark		1807	5 00	1 25	1 station.
Clay		1814	6 36	2 35	Mean of 4 stations.
Clinton		1832	5 10	2 00	Mean of 7 stations.
Crawford		1805	5 50	2 15	Mean of 3 stations.
Daviess		1806	6 50	3 15	Mean of 9 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Dearborn		1800	5 10	1 50	Mean of 11 stations
Decatur		1820	6 40	2 30	Mean of 9 stations.
Dekalb		1832	5 00	1 45	Mean of 12 stations
Delaware		1823	6 23	2 25	Mean of 18 stations.
Dubois		1805	6 37	3 05	Mean of 13 stations.
Elkhart		1830	5 27	2 05	Do.
Fayette		1817	6 16	2 15	Mean of 6 stations.
Floyd		1806	5 27	1 55	Mean of 3 stations.
Fountain		1822	6 50	2 50	Mean of 4 stations.
Franklin		1808	5 52	2 10	Mean of 10 stations.
Fulton		1834	5 51	2 40	Mean of 7 stations.
Gibson		1806	6 44	3 10	Mean of 13 stations
Grant		1834	5 45	2 35	Mean of 12 stations.
Greene		1814	7 03	3 00	Mean of 6 stations.
Hamilton		1822	5 42	1 35	Mean of 5 stations.
Hancock		1821	6 39	2 30	Mean of 11 stations.
Harrison		1806	6 24	2 50	Do.
Hendricks		1821	5 50	1 40	Do.
Henry		1821	6 11	2 00	Mean of 4 stations.
Howard		1844	4 36	1 45	Mean of 8 stations.
Huntington		1831	5 54	2 35	Mean of 7 stations.
Jackson		1814	6 35	2 35	Mean of 3 stations.
Jasper		1834	5 45	2 35	Mean of 16 stations.
Jay		1823	5 57	1 55	Mean of 11 stations.
Jefferson		1807	6 10	2 30	1 station.
Jennings		1809	5 34	1 50	Mean of 7 stations.
	Vernon	1895	1 46	1 30	County surveyor.
Johnson		1821	6 00	1 45	Mean of 9 stations.
	Franklin	1894	2 36	2 15	County surveyor.
Knox		1808	6 36	2 55	Mean of 10 stations.
	Vincennes	1880	4 22	3 05	C. & G. S.
Kosciusko		1835	5 53	2 45	Mean of 16 stations.
Lagrange		1831	5 20	2 00	Mean of 12 stations.
Lake		1834	6 27	3 15	Mean of 23 stations.
	Crown Point	1895	4 15	4 00	County surveyor.
Laporte		1833	6 00	2 50	Mean of 17 stations.
	Michigan City	1873	4 00	2 00	C. & G. S.
Lawrence		1812	7 03	3 20	Mean of 5 stations.
Madison		1822	6 03	2 00	Mean of 14 stations.
Marion		1821	5 57	1 50	Mean of 6 stations.
	Indianapolis	1880	2 47	1 30	C. & G. S.
Marshall		1833	6 14	3 05	Mean of 12 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Martin		1806	6 33	3 00	Mean of 6 stations.
Miami		1840	5 19	2 20	Mean of 12 stations.
Monroe		1820	6 34	2 25	Mean of 4 stations.
Montgomery		1821	6 41	2 25	Mean of 7 stations.
Morgan		1821	6 10	1 55	Mean of 13 stations.
	Martinsville	1896	2 11	1 55	County surveyor.
Newton		1835	6 28	3 20	Mean of 15 stations.
Noble		1834	5 17	2 05	Mean of 12 stations.
Ohio		1800	5 10	1 50	Mean of 4 stations.
Orange		1805	6 00	2 25	Mean of 7 stations.
Owen		1814	6 40	2 40	Do.
Parke		1820	6 36	2 25	Mean of 9 stations.
Perry		1805	6 30	3 00	Mean of 4 stations.
Pike		1805	6 37	3 05	Mean of 7 stations.
Porter		1834	6 38	3 30	Mean of 6 stations.
Posey		1806	6 57	3 20	Mean of 13 stations.
	Mount Vernon	1895	3 38	3 20	County surveyor.
	New Harmony	1880	5 05	3 45	C. & G. S.
Pulaski		1834	5 32	2 20	Mean of 11 stations.
Putnam		1820	6 25	2 15	Mean of 7 stations.
	Greencastle	1895	2 39	2 20	County surveyor.
Randolph		1817	5 50	1 50	Mean of 12 stations.
Ripley		1817	5 55	1 55	Mean of 2 stations.
Rush		1820	7 06	2 55	Mean of 9 stations.
St. Joseph		1834	5 50	2 40	Mean of 12 stations.
Scott		1810	6 10	2 25	Mean of 3 stations.
Shelby		1820	7 00	2 50	Mean of 10 stations.
Spencer		1805	6 30	3 00	Mean of 12 stations.
	Rockport	1895	3 50	3 30	County surveyor.
Starke		1834	5 32	2 20	Mean of 8 stations.
Steuben		1831	4 58	1 40	Mean of 12 stations.
Sullivan		1814	6 33	2 35	Mean of 11 stations.
Switzerland		1800	5 10	1 50	Mean of 4 stations.
Tippecanoe		1823	6 05	2 05	Mean of 9 stations.
Tipton		1843	4 47	1 50	Mean of 6 stations.
Union		1800	5 07	1 45	Mean of 7 stations.
	Liberty	1895	1 30	1 10	County surveyor.
Vanderburg				3 00	Estimated.
Vermilion		1818	6 54	2 50	Mean of 4 stations.
Vigo		1815	6 44	2 45	Mean of 8 stations.
	Terre Haute	1888	3 45	3 00	C. & G. S.
Wabash		1838	5 40	2 35	Mean of 16 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Warren		1826	6 35	2 55	Mean of 4 stations.
Warrick		1806	6 37	3 00	Mean of 9 stations.
	Canal	1895	3 38	3 20	County surveyor.
Washington		1807	6 16	2 40	Mean of 6 stations.
Wayne		1809	5 10	1 25	Mean of 8 stations.
	Richmond	1896	1 53	1 35	County surveyor.
Wells		1826	5 57	2 15	Mean of 9 stations.
White		1831	5 55	2 35	Mean of 13 stations.
	Monticello	1895	3 15	2 55	County surveyor.
	Reynolds	1874	3 30	1 40	N. A. S.
Whitley		1833	5 50	2 35	Mean of 8 stations.

INDIAN TERRITORY.

Observations for declination are very scanty, except in the western part of the Territory, where the lands are now being subdivided by the United States Geological Survey, and along the eastern border, where observations have been made by the Survey of the boundary with Arkansas.

The reductions on account of secular variation which have been adopted are similar to those used in Oklahoma, and are as follows:

Year.	Reduction.
	° ′
1890	0 30
1880	1 00
1870	1 30

The declination is east, and the above corrections are to be subtracted.

Reservations.	Subdivisions.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Chickasaw Nation.	Northeastern	1871	9 58	8 20	Mean of 25 stations.
	Northwestern	1871	10 46	9 05	Mean of 29 stations.
	Southeastern	1871	10 07	8 25	Mean of 33 stations.
	Southwestern	1871	10 30	8 50	Do.
Northeast reservations.		1875	9 12	7 35	Mean of 12 stations.
Choctaw Nation	Western	1895	8 16	8 00	Mean of 28 stations.
Creek Nation		1896	8 38	8 25	Mean of 5 stations.

IOWA.

The data for magnetic declination consist mainly of results from subdivisional surveys of the General Land Office, with a few from the Coast and Geodetic Survey, and a number of returns from county surveyors, the latter being, of course, of recent date. The surveys of the General Land Office which are used were made between the years 1837 and 1860. The line of no secular variation appears to have crossed the middle of Iowa about the year 1840, so that the reductions of most of these observations to 1900 are more or less affected by this change in the secular variation. To reduce these observations to 1900, the following table, derived from series of observations taken in this State, has been used:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1860	2 00
1880	1 20	1850	2 25
1870	1 40	1840	2 45

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adair				8 15	Estimated.
Adams	Corning	1895	9 10	8 50	County surveyor.
Allamakee		1851	9 00	6 35	Mean of 18 stations.
Appanoose	Centerville	1896	8 40	8 25	County surveyor.
Audubon				8 30	Estimated.
Benton		1843	9 35	6 55	Mean of 10 stations.
Blackhawk	Waterloo	1895	7 33	7 15	County surveyor.
Boone	Boone	1894	7 06	6 50	Do.
Bremer				7 00	Estimated.
Buchanan				6 45	Do.
Buena Vista		1855	10 36	8 25	Mean of 23 stations.
Butler				7 30	Estimated.
Calhoun	Manson	1894	9 25	9 00	County surveyor.
Carroll		1853	11 30	9 10	Mean of 30 stations.
Cass				8 15	Estimated.
Cedar		1838	9 03	6 15	Mean of 17 stations.
	Tipton	1895	6 45	6 30	County surveyor.
Cerro Gordo				7 45	Estimated.
Cherokee		1855	12 42	10 30	Mean of 17 stations.
	Cherokee	1869	11 32	9 50	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Chickasaw				7 00	Estimated.
Clarke		1895	8 00	7 40	County surveyor.
Clay		1857	10 56	8 45	Mean of 15 stations.
	Gillett Grove	1893	8 45	8 20	County surveyor.
Clayton		1843	8 48	6 10	Mean of 9 stations.
Clinton		1838	8 28	5 35	Mean of 24 stations.
	Dewitt	1878	6 30	5 05	County surveyor.
Crawford		1854	10 36	8 20	Mean of 10 stations.
Dallas				7 45	Estimated.
Davis		1895	8 10	7 50	County surveyor
Decatur		1895	7 57	7 40	Do.
Delaware		1893	5 25	5 00	Do.
Des Moines		1839	9 09	6 25	Mean of 16 stations.
Dickinson		1857	12 32	10 20	Mean of 12 stations.
Dubuque		1839	8 40	5 55	Mean of 20 stations.
	Dubuque	1895	6 30	6 10	County surveyor.
Emmet		1858	11 06	9 00	Mean of 12 stations.
Fayette		1849	7 40	5 15	Mean of 2 stations.
Floyd				7 30	Estimated.
Franklin				7 45	Do.
Fremont				8 45	Do.
Greene				8 25	Mean of 4 stations.
Grundy				7 15	Estimated.
Guthrie		1895	7 45	7 25	County surveyor.
Hamilton				7 45	Estimated.
Hancock				8 00	Do.
Hardin		1895	8 30	8 10	County surveyor.
Harrison				9 15	Estimated.
Henry		1837	9 29	6 35	Mean of 6 stations.
Howard				7 20	Estimated.
Humboldt		1853	10 02	7 40	Mean of 13 stations.
Ida		1854	11 24	9 00	Mean of 9 stations.
Iowa		1843	9 08	6 25	Mean of 11 stations.
	Marengo	1876	8 40	7 10	County surveyor.
Jackson		1839	8 19	5 35	Mean of 28 stations.
Jasper				7 30	Estimated.
Jefferson		1841	9 50	7 05	Mean of 6 stations.
Johnson		1840	9 00	6 15	Mean of 18 stations.
Jones		1838	9 22	6 30	Mean of 7 stations.
Keokuk		1843	9 32	6 50	Mean of 12 stations.
	Sigourney	1895	7 20	7 00	County surveyor.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Kossuth		1854	10 28	8 10	Mean of 4 stations.
Lee				6 00	Mean of 3 stations.
	Keokuk	1888	6 45	6 00	C. & G. S.
Linn		1842	9 32	6 50	Mean of 8 stations.
Louisa		1839	8 20	5 35	Mean of 14 stations.
Lucas				7 30	Estimated.
Lyon		1858	11 55	9 55	Mean of 6 stations.
Madison				8 00	Estimated.
Mahaska				7 15	Do.
Marion				7 30	Do.
Marshall	Marshalltown	1895	8 00	7 40	County surveyor.
Mills	Glenwood			9 35	Mean of 14 results by county surveyor.
Mitchell				7 30	Estimated.
Monona		1855	11 08	9 00	Mean of 4 stations.
Monroe				7 30	Estimated.
Montgomery				8 30	Do.
Muscatine		1838	7 57	5 10	Mean of 15 stations.
	Atalissa	1882	7 20	6 10	Nipher.
O'Brien		1857	11 24	9 15	Mean of 16 stations.
Osceola		1858	11 24	9 20	Mean of 11 stations.
	Sibley	1877	10 50	9 25	C. & G. S.
Page		1893	9 12	8 35	County surveyor.
Palo Alto		1854	11 45	9 30	Mean of 16 stations.
Plymouth		1855	11 53	9 40	Mean of 8 stations.
Pocahontas		1855	11 40	9 25	Mean of 36 stations.
	Rolfe	1894	9 33	9 10	County surveyor.
Polk	Des Moines	1888	8 28	7 40	C. & G. S.
Pottawattamie				9 30	Mean of 2 stations.
	Council Bluffs	1878	10 40	9 15	Proc. Royal Society.
Poweshiek				7 00	Estimated.
Ringgold				8 00	Do.
Sac		1853	10 02	7 40	Mean of 23 stations.
Scott	Davenport	1888	6 09	5 25	C. & G. S.
Shelby				8 30	Estimated.
Sioux		1856	11.17	9 05	Mean of 8 stations.
Story				6 40	Mean of 2 stations.
	Ames	1894	6 43	6 20	County surveyor.
Tama	Toledo	1877	8 36	7 10	Do.
Taylor	Bedford	1895	9 10	8 50	Do.
Union	Afton	1895	8 40	8 20	Do.
Van Buren				7 10	1 station.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Wapello		1844	9 49	7 15	Mean of 6 stations.
	Ottumwa	1895	7 25	7 10	County surveyor.
Warren				7 45	Estimated.
Washington		1839	9 28	6 45	Mean of 19 stations.
Wayne				7 30	Estimated.
Webster		1852	10 11	7 50	Mean of 17 stations.
Winnebago				8 00	Estimated.
Winneshiek		1850	8 00	5 35	Mean of 16 stations.
Woodbury		1855	12 00	9 50	Mean of 9 stations.
Worth				7 45	Estimated.
Wright				8 00	Do.

KANSAS.

Observations in Kansas are derived in the main from the surveys of standard lines and township exteriors by the General Land Office. In order to obtain data for a few counties, it was found necessary to draw from the subdivisional surveys. A few observations have been obtained from the Coast and Geodetic Survey, while numerous county surveyors have reported the declination in 1895 and 1896. The Land Office results in this State appear to be of excellent quality.

The line of no secular variation appears to have crossed Kansas between the years 1840 and 1855. The earliest Land Office surveys in the eastern part of the State were about the year 1855, while the latest ones in the western part of the State bear dates between 1870 and 1880, thus falling from fifteen to twenty-five years behind the line of no secular variation. The effect of the change in secular variation is hardly appreciable in this State, from a comparison of observations taken at the earliest and latest dates. The reductions to 1900, derived from series of observations, are as follows:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1860	2 15
1880	1 15	1850	2 35
1870	1 45		

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Allen		1867	11 30	9 35	Mean of 6 stations.
	Humboldt	1878	10 05	8 50	C. & G. S.
Anderson		1856	11 37	9 05	Mean of 4 stations.
Atchison		1855	11 08	8 45	Mean of 16 stations.
	Atchison	1892	8 43	8 15	City engineer.
Barber		1873	11 45	10 10	Mean of 36 stations.
Barton		1866	11 50	9 55	Mean of 10 stations.
	Great Bend	1878	11 05	9 50	C. & G. S.
Bourbon		1867	11 10	9 15	Mean of 6 stations.
Brown		1855	11 40	9 15	Mean of 23 stations.
	Hiawatha	1893	10 07	9 45	County surveyor.
Butler		1862	11 23	9 15	Mean of 23 stations.
	Eldorado	1895	9 35	9 20	County surveyor.
Chase		1856	11 40	9 15	Mean of 9 stations.
Chautauqua		1871	10 25	8 45	Mean of 16 stations.
Cherokee		1868	10 25	8 30	Mean of 20 stations.
	Weir	1896	8 03	7 50	County surveyor.
Cheyenne		1870	13 37	12 50	Mean of 19 stations.
Clark		1871	11 50	10 10	Mean of 27 stations.
Clay		1857	12 30	10 10	Mean of 16 stations.
	Clay Center	1895	9 59	9 40	County surveyor.
Cloud		1858	13 12	10 50	Mean of 12 stations.
Coffey		1856	12 26	10 10	Mean of 5 stations.
	Burlington	1895	9 31	9 15	County surveyor.
Comanche		1871	12 00	10 20	Mean of 33 stations.
Cowley	Winfield	1895	9 15	9 00	County surveyor.
Crawford		1867	12 03	10 05	Mean of 2 stations.
Decatur		1864	13 30	11 30	Mean of 7 stations.
Dickinson		1856	11 50	9 30	Mean of 10 stations.
	Abilene	1895	10 00	9 45	County surveyor.
Doniphan		1855	11 20	9 00	Mean of 12 stations.
	Troy	1895	9 54	9 35	County surveyor.
Douglas	Lawrence	1878	9 52	8 35	C. & G. S.
Edwards		1871	12 05	10 25	Mean of 12 stations.
	Kinsley	1895	10 46	10 30	County surveyor.
Elk		1867	11 27	9 30	Mean of 7 stations.
	Moline	1895	9 10	8 50	County surveyor.
Ellis		1868	12 10	10 20	Mean of 18 stations.
	Ellis	1872	12 25	10 45	C. & G. S.
	Hays	1895	11 20	11 00	County surveyor.
Ellsworth		1859	12 38	10 20	Mean of 7 stations.
	Ellsworth	1895	10 17	10 00	County surveyor.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Finney		1870	12 35	10 50	Mean of 15 stations.
Ford		1872	11 48	10 15	Mean of 7 stations.
	Dodge	1895	10 30	10 15	County surveyor.
Franklin		1856	11 28	9 00	Mean of 1 stations.
Garfield		1870	12 40	11 00	Mean of 8 stations.
Geary		1857	12 10	9 50	Mean of 2 stations.
	Junction City	1888	10 05	9 15	C. & G. S.
Gove		1869	13 25	11 40	Mean of 12 stations.
Graham		1867	12 50	11 00	Mean of 15 stations.
Grant		1873	12 27	10 50	Mean of 8 stations.
Gray		1872	12 25	10 45	Mean of 5 stations.
	Cimarron	1895	10 43	10 25	County surveyor.
Greeley		1872	12 53	12 00	Mean of 13 stations.
Greenwood		1867	11 30	9 25	Mean of 21 stations.
	Eureka	1895	9 32	9 15	County surveyor.
Hamilton		1872	12 45	11 00	Mean of 14 stations.
Harper		1876	10 50	9 10	Mean of 21 stations.
	Anthony	1896	9 50	9 35	County surveyor.
Harvey		1857	11 47	9 25	Mean of 5 stations.
	Newton	1895	10 05	9 50	County surveyor.
Haskell		1873	12 22	10 50	Mean of 13 stations
Hodgeman		1870	12 06	10 20	Mean of 19 stations
	Jetmore	1895	11 10	10 55	County surveyor.
Jackson		1855	11 46	9 20	Mean of 5 stations.
	Holton	1895	9 37	9 20	County surveyor.
Jefferson		1855	10 53	8 30	Mean of 4 stations.
Jewell		1862	12 28	10 15	Mean of 14 stations.
	Jewell	1894	10 40	10 20	County surveyor.
Johnson		1856	10 30	8 05	Mean of 9 stations.
Kearney		1871	12 48	11 10	Mean of 8 stations.
Kingman		1869	11 30	9 40	Mean of 24 stations.
Kiowa		1869	12 05	10 15	Mean of 30 stations.
Labette	Parsons	1880	9 33	8 20	Nipher.
Lane		1870	12 50	11 05	Mean of 12 stations.
Leavenworth		1855	11 20	8 55	Mean of 13 stations.
	Ft. Leavenworth	1858	11 00	8 40	Stone.
Lincoln		1859	12 30	10 15	Mean of 9 stations.
Linn		1856	11 20	8 55	Mean of 6 stations.
	Mound City	1895	8 26	8 10	County surveyor.
Logan		1870	13 10	11 25	Mean of 9 stations.
Lyon		1856	12 25	10 00	Mean of 8 stations.
	Emporia	1888	10 08	9 20	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
McPherson		1858	12 26	10 05	Mean of 12 stations.
	McPherson	1894	9 56	9 35	County surveyor.
Marion		1857	11 53	9 35	Mean of 12 stations.
	Marion	1893	9 57	9 30	County surveyor.
Marshall		1855	11 50	9 25	Mean of 18 stations.
	Marysville	1895	9 19	9 00	County surveyor.
Meade		1873	11 55	10 20	Mean of 9 stations.
	Meade	1896	11 10	10 55	County surveyor.
Miami		1856	11 48	9 20	Mean of 4 stations.
Mitchell		1862	12 50	10 40	Mean of 9 stations.
Montgomery	Cherryvale	1895	8 28	8 10	County surveyor.
Morris		1856	11 45	9 20	Mean of 8 stations.
Morton		1874	12 20	10 50	Mean of 15 stations.
Nemaha		1855	11 20	8 55	Mean of 22 stations.
Neosho		1867	12 03	10 05	Mean of 3 stations.
Ness		1869	12 40	10 50	Mean of 19 stations.
	Ness City	1895	11 22	11 05	County surveyor.
Norton		1865	13 00	11 00	Mean of 14 stations.
Osage		1856	12 48	10 20	Mean of 3 stations.
	Lyndon	1895	9 29	9 10	County surveyor.
Osborne		1864	12 09	10 10	Mean of 12 stations.
	Osborne	1895	10 58	10 40	County surveyor.
Ottawa		1858	12 00	9 40	Mean of 9 stations.
Pawnee		1867	12 30	10 30	Mean of 12 stations.
	Larned	1893	10 56	10 30	County surveyor.
Phillips		1859	13 23	11 10	Mean of 18 stations.
	Phillipsburg	1895	10 58	10 40	County surveyor.
Pottawatomie		1855	12 00	9 35	Mean of 11 stations.
	Westmoreland	1895	9 08	8 50	County surveyor.
Pratt	Pratt	1895	10 24	10 05	Do.
Rawlins		1870	13 20	11 35	Mean of 17 stations.
Reno		1859	12 25	10 05	Mean of 9 stations.
	Hutchinson	1895	9 50	9 30	County surveyor.
Republic		1858	12 03	9 45	Mean of 9 stations.
Rice		1866	11 55	9 50	Do.
	Lyons	1895	10 03	9 45	County surveyor.
Riley		1856	11 50	9 30	Mean of 8 stations.
	Manhattan	1895	10 09	9 50	County surveyor.
Rooks		1865	12 50	10 50	Mean of 15 stations.
	Stockton	1895	11 13	10 55	County surveyor.
Rush	Lacrosse	1895	10 22	10 05	Do.
	Alexander	1880	12 10	10 55	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Russell		1866	12 00	10 00	Mean of 15 stations.
Saline		1858	12 15	9 55	Mean of 9 stations.
	Salina			10 35	County surveyor. Mean of 228 results.
Scott		1870	13 05	11 20	Mean of 15 stations.
Sedgwick		1859	11 50	9 30	Mean of 12 stations.
	Wichita	1895	10 30	10 10	County surveyor.
Seward		1874	11 54	10 25	Mean of 13 stations.
Shawnee		1856	12 45	10 20	1 station.
Sheridan		1869	13 22	11 40	Mean of 10 stations.
Sherman		1871	13 15	11 30	Mean of 13 stations.
	Goodland	1888	12 24	11 40	C. & G. S.
Smith		1862	13 15	11 05	Mean of 11 stations.
	Smith Center	1895	11 39	11 20	County surveyor.
Stafford		1866	11 31	9 35	Mean of 4 stations.
	St. John	1896	10 30	10 15	County surveyor.
Stanton		1873	12 36	11 00	Mean of 15 stations.
Stevens		1874	12 18	11 35	Mean of 8 stations.
Sumner		1871	11 20	9 40	Mean of 29 stations.
Thomas		1870	13 17	11 30	Mean of 23 stations.
Trego		1868	12 55	11 00	Mean of 15 stations.
Wabaunsee		1856	11 44	9 20	Mean of 9 stations.
	Alma	1892	10 04	9 35	County surveyor.
Wallace		1872	13 00	11 20	Mean of 15 stations.
	Wallace	1872	13 18	11 40	N. A. S.
Washington		1856	11 57	9 30	Mean of 19 stations.
	Washington	1896	10 37	10 20	County surveyor.
Wichita		1870	13 17	11 30	Mean of 8 stations.
Wilson		1867	11 14	9 20	Mean of 12 stations.
Woodson		1867	11 48	9 55	Mean of 7 stations.
	Yates Center	1895	9 20	9 00	County surveyor.
Wyandotte		1855	11 13	8 50	Mean of 7 stations.

KENTUCKY.

Observations for magnetic declination in Kentucky are very scanty, only 39 counties out of 119 being represented. These observations are from returns of county surveyors by the United States Coast and Geodetic Survey, with a few from miscellaneous sources. Nearly all of them are of recent years, none being earlier than 1859, the date of a few which were observed in connection with the survey of the southern boundary of the State.

They have been reduced to 1900 by the application of corrections derived from series of observations in this State and Tennessee. They are set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1860	2 10
1880	1 25	1850	2 20
1870	1 40	1840	2 50

The line of zero declination crosses this State. East of it the declination is west and is distinguished by the letter W. West of it the declination is east and is distinguished by the letter E. The above corrections are to be added to west declinations and subtracted from east declinations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adair				2 15 E.	Estimated.
Allen				3 30 E.	Do.
Anderson	Leathers Store	1894	1 51 E.	1 30 E.	County surveyor.
Ballard				4 30 E.	Estimated.
Barren	Cave City	1875	5 55 E.	4 25 E.	N. A. S.
Bath				0 30 E.	Estimated.
Bell				0 30 E.	Do.
Boone				1 30 E.	Do.
Bourbon				0 45 E.	Do.
Boyd				0 30 W.	Do.
Boyle	Danville	1889	2 02 E.	1 20 E.	C. & G. S.
Bracken				0 30 E.	Estimated.
Breathitt				0 15 E.	Do.
Breckinridge	Hardinsburg	1895	2 15 E.	2 00 E.	County surveyor.
Bullitt				2 15 E.	Estimated.
Butler		1895	1 30 E.	1 15 E.	County surveyor.
Caldwell				4 15 E.	Estimated.
Calloway				5 35 E.	Mean of 2 stations.
Campbell				1 00 E.	Estimated.
Carlisle				4 30 E.	Do.
Carroll				2 00 E.	Do.
Carter		1896	1 30 W.	1 45 W.	County surveyor.
	Grayson	1881	1 28 E.	0 10 E.	C. & G. S.
Casey				2 00 E.	Estimated.
Christian	Crofton	1875	6 15 E.	4 45 E.	N. A. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Clark	Winchester	1895	2 28 E.	2 10 E.	County surveyor.
Clay				0 30 E.	Estimated.
Clinton		1859	4 30 E.	2 20 E.	Boundary survey.
Crittenden				4 00 E.	Estimated.
Cumberland				2 30 E.	Do.
Daviess				3 30 E.	Do.
Edmonson				3 00 E.	Do.
Elliott				0 00	Do.
Estill				0 45 E.	Do.
Fayette				1 15 E.	Do.
Fleming	Flemingsburg	1881	1 45 E.	0 25 E.	C. & G. S.
Floyd				0 15 W.	Estimated.
Franklin				1 30 E.	Do.
Fulton				5 00 E.	Mean of 3 stations.
	Hickman	1895	5 04 E.	4 45 E.	County surveyor.
Gallatin				1 30 E.	Estimated.
Garrard				1 15 E.	Do.
Grant				2 15 E.	Do.
Graves	Mayfield	1881	5 13 E.	3 50 E.	C. & G. S.
Grayson	Litchfield	1881	3 20 E.	2 00 E.	Do.
Greene				2 30 E.	Estimated.
Greenup				0 30 W.	Do.
Hancock	Patesville	1893	4 40 E.	4 10 E.	County surveyor.
Hardin				2 30 E.	Estimated.
Harlan				0 15 E.	Do.
Harrison	Cynthiana	1881	2 30 E.	1 10 E.	C. & G. S.
Hart				2 30 E.	Estimated.
Henderson	Henderson	1895	4 15 E.	4 00 E.	County surveyor.
Henry				2 00 E.	Estimated.
Hickman	Clinton	1895	4 45 E.	4 30 E.	County surveyor.
Hopkins	Madisonville	1881	5 06 E.	3 45 E.	C. & G. S.
Jackson				0 45 E.	Estimated.
Jefferson				2 15 E.	Do.
Jessamine	Nicholasville	1875	2 48 E.	1 15 E.	C. & G. S.
Johnson				0 15 W.	Estimated.
Kenton				1 15 E.	Do.
Knott				0 00	Do.
Knox				0 00	Do.
Larue				2 30 E.	Do.
Laurel				0 45 E.	Do.
Lawrence				0 15 W.	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Lee				0 30 E.	Estimated.
Leslie				0 15 E.	Do.
Letcher				0 00	Do.
Lewis				1 00 E.	Mean of 3 stations.
Lincoln	Stanford	1881	4 15 E.	2 55 E.	C. & G. S.
Livingston				5 40 E.	Mean of 3 results by C. & G. S.
Logan				4 00 E.	Estimated.
Lyon				4 00 E.	Do.
McCracken	Paducah	1865	6 45 E.	4 50 E.	C. & G. S.
McLean	Sacramento	1894.	4 45 E.	4 20 E.	County surveyor.
Madison				1 00 E.	Estimated.
Magoffin				0 00	Do.
Marion	Lebanon	1881	3 45 E.	2 25 E.	C. & G. S.
Marshall				4 15 E.	Estimated.
Martin				0 30 W.	Do.
Mason	Maysville	1894	0 18 W.	0 40 W.	County surveyor.
Meade	Brandenburg	1895	5 15 E.	4 55 E.	Do.
Menifee				0 30 E.	Estimated.
Mercer				1 30 E.	Do.
Metcalfe				2 30 E.	Do.
Monroe		1895	2 25 E.	2 15 E.	Mean of 5 results.
Montgomery				0 30 E.	Estimated.
Morgan				0 00	Do.
Muhlenberg	Central City	1886	3 36 E.	2 40 E.	C. & G. S.
Nelson				2 15 E.	Estimated.
Nicholas				0 30 E.	Do.
Ohio				3 30 E.	Do.
Oldham				2 15 E.	Do.
Owen				1 30 E.	Do.
Owsley				0 30 E.	Do.
Pendleton	Tur	1896	1 05 E.	0 50 E.	County surveyor.
	Falmouth	1872	3 22 E.	1 45 E.	C. & G. S.
	Portland	1875	3 38 E.	2 05 E.	N. A. S.
Perry				0 15 E.	Estimated.
Pike				0 30 W.	Do.
Powell				0 30 E.	Do.
Pulaski				1 30 E.	Do.
Robertson				0 30 E.	Do.
Rockcastle	Livingston	1881	1 37 E.	0 15 E.	C. & G. S.
Rowan				0 00	Estimated.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Russell				2 00 E.	Estimated.
Scott				1 15 E.	Do.
Shelby	Shelbyville	1871	3 02 E.	1 25 E.	C. & G. S.
Simpson		1859	7 20 E.	5 10 E.	Boundary survey.
Spencer				2 00 E.	Estimated.
Taylor				2 15 E.	Do.
Todd	Guthrie	1875	6 45 E.	5 15 E.	N. A. S.
Trigg		1859	6 48 E.	4 35 E.	Boundary survey.
Trimble				2 00 E.	Estimated.
Union				4 15 E.	Do.
Warren		1896	5 00 E.	4 45 E.	County surveyor.
	Oakland	1871	6 15 E.	4 35 E.	C. & G. S.
Washington				2 00 E.	Estimated.
Wayne				1 30 E.	Do.
Webster	Providence	1895	4 30 E.	4 20 E.	County surveyor.
Whitley	Williamsburg	1873	2 04 E.	0 30 E.	N. A. S.
Wolfe				0 30 E.	Estimated.
Woodford				1 30 E.	Do.

LOUISIANA.

Observations in Louisiana are derived in the main from the subdivisional surveys of the General Land Office, with a few returns from parish surveyors and scattering data from other sources. The Land Office surveys are of date between 1835 and 1880, and appear to be of fairly good quality.

The line of no secular variation appears to have crossed Louisiana about 1830, and thus many of the Land Office observations are complicated with the change in secular variation. They have been reduced to the epoch 1900 by the application of the figures given in the following table, derived from series observed within the State:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1850	2 20
1880	1 00	1840	2 30
1870	1 30	1830	2 35
1860	2 10		

The declination is east, and the above corrections are to be subtracted.

Parish.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Acadia		1859	8 23	6 15	Mean of 14 stations.
Ascension		1847	8 22	6 00	Mean of 3 stations.
		1896	6 00	5 45	Mean of parish by parish surveyor.
Assumption		1843	8 38	6 15	Mean of 22 stations.
Avoyelles		1850	8 33	6 15	Mean of 18 stations.
Bienville				6 40	Estimated.
Bossier				6 50	Do.
Caddo	Shreveport	1888	7 24	6 50	C. & G. S.
Calcasieu		1867	8 20	6 40	Mean of 35 stations.
Caldwell		1842	8 40	6 10	Mean of 3 stations.
Cameron		1841	8 44	6 15	Mean of 7 stations.
Catahoula		1844	8 38	6 15	Mean of 20 stations.
Claiborne				6 30	Estimated.
Concordia		1837	8 32	6 00	Mean of 8 stations.
De Soto				6 50	Estimated.
East Baton Rouge.		1854	8 06	6 00	Mean of 25 stations.
		1896	6 00	5 45	Mean of parish by parish surveyor.
	Baton Rouge	1872	7 00	5 35	C. & G. S.
East Carroll		1846	8 10	5 45	Mean of 7 stations.
	Lake Providence	1894	6 30	6 15	Parish surveyor.
East Feliciana		1853	8 00	5 45	Mean of 7 stations.
Franklin		1838	8 28	6 00	Mean of 12 stations.
Grant				6 30	Estimated.
Iberia		1846	8 40	6 15	Mean of 25 stations.
Iberville		1849	8 28	6 10	Mean of 11 stations.
Jackson				6 30	Estimated.
Jefferson		1847	8 20	5 55	Mean of 12 stations.
Lafayette		1852	8 20	6 00	Do.
Lafourche		1845	8 30	6 05	Mean of 50 stations.
Lincoln		1895	7 00	6 45	1 station.
Livingston				5 50	Estimated.
Madison		1838	8 25	5 55	Mean of 15 stations.
Morehouse		1854	8 25	6 10	Mean of 23 stations.
Natchitoches	Natchitoches	1895	7 05	6 50	Parish surveyor.
Orleans		1867	7 36	5 55	Mean of 5 stations.
	New Orleans	1870	7 00	5 30	C. & G. S.
Ouachita		1848	8 30	6 10	Mean of 5 stations.
	Monroe	1872	7 36	6 10	N. A. S.
Plaquemines		1852	8 23	6 00	Mean of 16 stations.
Pointe Coupee		1852	8 35	6 15	Do.
Rapides		1873	8 19	7 00	Mean of 6 stations.

Parish.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Rapides	Alexandria	1872	7 45	6 25	N. A. S.
Red River				6 40	Estimated.
Richland		1841	8 23	5 55	Mean of 17 stations.
Sabine		1895	6 30	6 15	1 station.
St. Bernard		1857	7 36	5 20	Do.
St. Charles		1846	8 20	5 55	Mean of 4 stations.
St. Helena				5 40	Estimated.
St. James		1845	8 30	6 05	Mean of 11 stations.
		1896	6 00	5 45	Mean of parish by parish surveyor.
St. John the Baptist.		1848	8 33	6 10	Mean of 6 stations.
		1896	6 00	5 45	Mean of parish by parish surveyor.
St. Landry		1854	8 34	6 20	Mean of 52 stations.
St. Martin		1855	8 10	6 05	Mean of 18 stations.
St. Mary		1845	8 46	6 20	Mean of 23 stations.
	Morgan	1886	6 30	5 45	C. & G. S.
St. Tammany		1848	7 52	5 30	Mean of 32 stations.
	Covington	1895	5 45	5 30	Parish surveyor.
Tangipahoa		1840	7 57	5 25	Mean of 13 stations.
	Chappeau	1895	6 00	5 45	Parish surveyor.
Tensas		1839	8 20	5 50	Mean of 16 stations.
Terrebonne		1843	8 50	6 25	Mean of 62 stations.
Union				6 20	Estimated.
Vermilion		1847	8 37	6 10	Mean of 30 stations.
Vernon		1877	7 40	6 30	Mean of 4 stations.
Washington		1845	7 55	5 30	Mean of 20 stations.
Webster	Minden	1895	8 30	8 15	Parish surveyor.
West Baton Rouge.		1844	8 34	6 10	Mean of 6 stations.
		1896	6 40	6 25	Mean of parish by parish surveyor.
West Carroll		1855	8 22	6 05	Mean of 11 stations.
West Feliciana		1852	8 04	5 25	Mean of 12 stations.
Winn				6 30	Estimated.

MAINE.

Observations in Maine are derived mainly from the collection of the United States Coast and Geodetic Survey, with a few returns from county surveyors. They range in date from 1840 down to the present time.

Wherever in the county table following there is given the mean of several stations opposite the name of the county, it is understood that this mean includes the stations within the county which follow.

The line of no secular variation crossed Maine many years before the beginning of the present century, and consequently none of the earlier observations are complicated with the change in secular variation. They have been reduced to the epoch 1900 by the application of the following corrections derived from the series observed in the State:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 20	1860	2 30
1880	0 50	1850	3 00
1870	1 45	1840	3 55

The declination is west, and the corrections for secular variation are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Androscoggin	Mount Sebattis	1853	12 53	15 45	C. & G. S.
Aroostook				21 15	Mean of 16 stations.
	Houlton	1887	19 00	19 30	C. & G. S.
	Presque Isle	1887	20 04	20 35	Do.
	Fort Fairfield	1841	17 27	21 15	Boundary survey.
	Fort Kent	1843	17 30	21 10	Do.
Cumberland				16 00	Mean of 10 stations.
	Portland	1887	13 50	14 20	C. & G. S.
	Harpswell	1863	14 25	16 40	Do.
	Freeport	1863	14 12	16 30	Do.
	Brunswick	1873	14 18	15 45	Do.
Franklin	Farmington	1887	14 56	15 25	Do.
Hancock				19 10	Mean of 6 stations.
	Southwest Harbor.	1856	15 25	18 05	C. & G. S.
	Mount Desert	1856	15 15	17 55	Do.
Kennebec	Waterville	1840	12 48	16 45	Getchell's Tables
	North Vassalboro	1880	16 00	16 50	Do.
Knox	Rockland	1863	15 02	17 20	C. & G. S.
	Camden	1854	13 58	16 45	Do.
	West Thomaston	1840	12 10	16 05	Getchell's Tables.
Lincoln	Damariscotta	1887	15 13	15 40	C. & G. S.
Oxford	Greenwood	1845	12 08	15 35	Getchell's Tables.
	Bethel	1845	11 50	15 15	Do.
	Rumford	1840	11 10	15 05	Do.
	Dixfield	1840	12 10	16 05	Do.
Penobscot	Bangor	1879	16 30	17 25	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Penobscot	Mattawamkeag	1887	17 56	18 25	C. & G. S.
	Hampden	1840	13 22	17 15	Getchell's Tables.
	Orono	1878	16 40	17 40	Do.
Piscataquis				18 00	Mean of 3 stations.
	Greenville	1887	16 48	17 15	C. & G. S.
Sagadahoc	Bath	1863	12 52	15 10	Do.
Somerset	Pittsfield	1887	16 00	16 30	Do.
Waldo	Belfast	1863	15 30	17 45	Do.
Washington	Steuben	1895	17 05	17 15	County surveyor.
	Cherryfield	1895	17 05	17 15	Do.
	Machias	1895	18 21	18 30	Do.
	Lubec	1895	19 28	19 40	Do.
	Eastport	1895	19 42	19 50	Do.
	Machiasport	1887	17 43	18 10	C. & G. S.
	Cooper	1859	16 32	19 05	Do.
	Calais	1857	15 21	18 00	Do.
	Vanceboro	1887	18 22	18 50	Do.
	Danforth	1887	18 25	18 55	Do.
York	Kittery Point	1879	12 31	13 25	Do.
	Kennebunkport	1851	11 23	14 20	Do.

MARYLAND.

Observations for declination in Maryland are scanty. They are derived in the main from the Coast and Geodetic Survey, with a few from county surveyors. The dates of these observations range from 1845 to 1895, being, therefore, far removed in time from the line of no secular variation, which crossed Maryland shortly after 1800. The following table of reductions to 1900 on account of secular variation has been applied in this State. It was derived from a series of observations in Maryland, Delaware, District of Columbia, Virginia, and West Virginia.

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1840	3 30
1880	1 00	1830	4 00
1870	1 55	1820	4 10
1860	2 25	1810	4 20
1850	3 00		

The declination is west, and the above corrections are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Allegany	Cumberland	1893	3 43	4 05	County surveyor.
	Lonaconing	1879	3 00	4 05	C. & G. S.
Anne Arundel				5 00	C. & G. S. Mean of 5 stations.
	Annapolis	1879	4 26	5 30	C. & G. S.
Baltimore	Fort Henry	1885	4 30	5 15	Do.
	Rosanne	1845	2 10	5 25	Do.
Baltimore City		1885	4 29	5 15	Do.
Calvert				4 45	Estimated.
Caroline				5 45	Do.
Carroll				5 30	Do.
Cecil	Calvert	1871	2 50	4 45	C. & G. S.
Charles				4 30	Estimated.
Dorchester	Vienna	1886	4 50	5 35	C. & G. S.
Frederick	Libertytown	1884	4 20	5 10	County surveyor.
Garrett				3 45	Estimated.
Harford				5 40	C. & G. S. Mean of 2 stations.
Howard				5 15	Estimated.
Kent		1847	2 30	5 40	C. & G. S.
Montgomery				4 45	C. & G. S. Mean of 2 stations.
Prince George		1868	2 51	4 50	C. & G. S.
	Cheltenham	1889	4 10	4 45	Do.
Queen Anne	Kent Island			5 35	Mean of 2 stations.
St. Mary				4 30	Estimated.
Somerset				5 00	Do.
Talbot	Oxford	1856	2 42	5 25	C. & G. S.
Washington	Maryland H'ghts	1870	2 56	4 50	Do.
	Penmar	1895	3 50	4 05	County surveyor.
Wicomico				5 15	Estimated.
Worcester				5 05	Mean of 2 stations. C. & G. S.

MASSACHUSETTS.

The data for Massachusetts are derived mainly from the Coast Survey compilation, to which have been added a few returns from city engineers. In each case where the mean of several stations is given for the county, it is to be understood that it includes the stations which are given individually.

The line of no secular variation crossed Massachusetts about 1790; consequently, since the earliest of the observations herewith presented bear date 1838, none of them are affected by the change in the secular variation. They have been reduced to the epoch 1900 by the application of reductions deduced from the series observed in western New England.

The following table shows the reductions to the epoch 1900:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 20	1840	3 40
1880	0 45	1830	4 40
1870	1 25	1820	5 20
1860	2 05	1810	5 50
1850	2 55		

The declination is west, and the reduction for secular variation is to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Barnstable	Hyannis	1846	9 22	12 35	C. & G. S.
	Chatham	1860	11 12	13 15	Do.
	Wellfleet	1860	10 43	12 50	Do.
	Provincetown	1860	11 24	13 30	Do.
Berkshire	North Adams	1876	10 30	11 30	N. A. S.
	Pittsfield	1895	10 26	10 35	City surveyor.
	Williamstown	1866	10 22	12 05	C. & G. S.
Bristol				12 25	Mean of 2 stations.
	Fairhaven	1845	8 54	12 10	C. & G. S.
Dukes				12 10	Mean of 6 stations.
	Vineyard Haven	1875	10 35	11 40	C. & G. S.
	Tarpaulin Cove	1846	9 12	12 25	Do.
	Edgartown	1889	11 10	11 35	Town surveyor.
Essex				13 45	Mean of 12 stations.
	Salem	1887	12 38	13 05	C. & G. S.
	Annisquam	1849	11 37	14 35	Do.
	Rockport	1859	11 37	13 35	Do.
	Ipswich	1859	11 14	13 15	Do.
	Lynn	1877	11 15	12 10	Do.
Franklin	Deerfield	1859	9 25	11 25	Do.
	Greenfield	1876	10 20	11 20	N. A. S.
Hampden				11 30	Mean of 4 stations.
	Springfield	1894	10 30	10 40	City engineer.
	Southwick	1838	8 15	12 05	Silliman's Journal.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Hampshire				10 50	Mean of 3 stations.
	Easthampton	1862	9 05	11 00	C. & G. S.
	Chesterfield	1859	8 54	10 55	Do.
	South Hadley	1875	9 28	10 35	Report Chief of Engineers.
Middlesex				12 45	Mean of 4 stations.
	Cambridge	1879	11 46	12 35	C. & G. S.
	Lowell	1876	10 48	11 50	N. A. S.
	Waltham	1895	12 22	12 30	City engineer.
Nantucket				13 20	Mean of 3 stations.
	Nantucket	1882	12 24	13 05	Engineer Wannaconnet Water Co. Mean of 24 observations.
Norfolk	Blue Hill	1845	9 13	12 30	C. & G. S.
Plymouth				12 50	Mean of 5 stations.
	Nantasket	1847	9 02	12 10	C. & G. S.
	Plymouth	1876	10 55	11 55	N. A. S.
	Bridgewater	1882	11 26	12 05	C. & G. S.
Suffolk	South Boston	1872	11 15	12 30	Do.
Worcester				12 00	Mean of 3 stations.
	Worcester	1883	10 47	11 25	City engineer. Mean of many observations.

MICHIGAN.

Observations in Michigan are mainly derived from three sources: First, the General Land Office; second, the United States Lake Survey; and third, county surveyors.

In the table the mean results by counties from observations by the General Land Office and by the Lake Survey are given independently. Those from the General Land Office are scattered somewhat uniformly over the areas of the counties, while those by the Lake Survey are commonly confined to the lake shores. They do not differ greatly in date, but it will be seen the results, when reduced to the epoch 1900, are often discordant. In certain cases, particularly upon the upper peninsula, this disagreement can be accounted for by the difference between the locations of the observations, as the counties are large; moreover, in many of these counties local attraction, owing to the presence of iron ore, is known to be great.

The line of no secular change is assumed to have crossed Michigan about 1820, although the date is somewhat later in the western part of the upper peninsula. The reductions to 1900 have been derived directly from observations taken within the State, and are given in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 45	1840	3 20
1880	1 25	1830	4 10
1870	2 10	1820	5 00
1860	2 35	1810	4 20
1850	3 00		

The line of zero of magnetic declination crosses this State from north to south. Declinations east of this line are west and are distinguished by the letter W. Those west of this line are east and are distinguished by the letter E. The corrections on account of secular variation are to be added to west declinations and subtracted from east declinations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Alcona		1842	1 49 E.	1 25 W.	Mean of 19 stations by Land Office.
		1853	0 56 E.	2 00 W.	Mean of 4 stations by Lake Survey.
Alger		1845	4 18 E.	1 10 E.	Mean of 8 stations by Land Office.
		1864	3 24 E.	1 00 E.	Mean of 5 stations by Lake Survey.
	Grand Marais	1867	2 02 E.	0 20 W.	Lake Survey.
Allegan		1832	5 39 E.	1 40 E.	Mean of 24 stations by Land Office.
	Allegan	1893	0 55 E.	0 30 E.	County surveyor.
	Saugatuck	1871	2 25 E.	0 20 E.	Lake Survey.
Alpena		1845	1 50 E.	1 20 W.	Mean of 20 stations by Land Office.
		1858	0 58 W.	3 35 W.	Mean of 4 stations by Lake Survey.
	Alpena	1858	0 24 W.	3 00 W.	Lake Survey.
Antrim		1848	3 08 E.	0 00	Mean of 18 stations by Land Office.
		1860	2 25 E.	0 10 W.	Mean of 2 stations by Lake Survey.
Arenac		1844	2 18 E.	0 50 W.	Mean of 15 stations by Land Office.
		1857	1 46 E.	1 00 W.	Mean of 2 stations by Lake Survey.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Arenac	Standish	1895	2 00 W.	2 20 W.	County surveyor.
Baraga		1824	7 56 E.	3 20 E.	1 station by Lake Survey.
Barry		1829	5 03 E.	0 55 E.	Mean of 16 stations by Land Office.
	Hastings	1896	0 56 E.	0 40 E.	County surveyor.
Bay		1839	2 29 E.	0 50 W.	Mean of 16 stations by Land Office.
		1856	1 26 E.	1 20 W.	Mean of 4 stations by Lake Survey.
Benzie		1842	3 35 E.	0 20 E.	Mean of 12 stations by Land Office.
Berrien		1829	5 37 E.	1 25 E.	Mean of 23 stations by Land Office.
		1871	4 13 E.	2 10 E.	Mean of 2 stations by Lake Survey.
	St. Joseph	1871	3 53 E.	1 50 E.	Lake Survey.
Branch		1827	4 15 E.	0 05 W.	Mean of 15 stations by Land Office.
	Kinderhook	1890	1 00 E.	0 15 E.	County surveyor.
Calhoun		1829	5 09 E.	1 00 E.	Mean of 20 stations by Land Office.
		1893	1 04 E.	0 35 E.	County surveyor.
	Marshall	1876	1 42 E.	0 00	Lake Survey.
Cass		1829	5 25 E.	1 10 E.	Mean of 13 stations by Land Office.
	Penn	1896	1 40 E.	1 25 E.	County surveyor.
Charlevoix		1843	3 16 E.	0 00	Mean of 15 stations by Land Office.
	Charlevoix	1880	0 00	1 25 W.	County surveyor.
Cheboygan		1847	3 32 E.	0 25 E.	Mean of 33 stations by Land Office.
		1851	1 52 E.	1 00 W.	Mean of 5 stations by Lake Survey.
Chippewa		1845	1 33 E.	1 35 W.	Mean of 17 stations by Land Office.
		1858	1 02 E.	1 35 W.	Mean of 16 stations by Lake Survey.
	Sault Ste. Marie	1880	1 05 W.	2 30 W.	Lake Survey.
Clare		1847	3 39 E.	0 30 E.	Mean of 15 stations by Land Office.
Clinton		1831	3 50 E.	0 15 W.	Mean of 14 stations by Land Office.
	Elsie	1895	0 07 W.	0 25 W.	County surveyor.
Crawford		1849	2 36 E.	0 25 W.	Mean of 17 stations by Land Office.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Delta		1863	2 25 E.	0 00	Mean of 8 stations by Lake Survey.
		1895	0 13 E.	0 05 W.	Mean of 11 stations by county surveyor.
Dickinson				3 00 E.	Estimated.
Eaton		1833	4 08 E.	3 00 E.	Mean of 16 stations by Land Office.
Emmet		1840	3 21 E.	0 00	Mean of 15 stations by Land Office.
		1858	2 44 E.	0 00	Mean of 13 stations by Lake Survey.
Genesee		1823	3 41 E.	1 10 W.	Mean of 7 stations by Land Office.
Gladwin		1850	2 41 E.	0 20 W.	Mean of 12 stations by Land Office.
Gogebic				4 30 E.	Estimated.
Grand Traverse		1844	2 54 E.	0 15 W.	Mean of 17 stations by Land Office.
		1860	2 06 E.	0 30 W.	Mean of 7 stations by Lake Survey.
	Petoskey	1893	0 20 E.	0 10 W.	County surveyor.
Gratiot		1831	3 08 E.	1 00 W.	Mean of 13 stations by Land Office.
	St. Louis	1876	1 00 E.	0 40 W.	Lake Survey.
Hillsdale		1825	4 57 E.	0 20 E.	Mean of 23 stations by Land Office.
	Hillsdale	1896	0 26 E.	0 10 E.	County surveyor.
Houghton		1864	5 05 E.	2 40 E.	Mean of 8 stations by Lake Survey.
Huron		1835	2 39 E.	1 05 W.	Mean of 31 stations by Land Office.
		1855	0 27 E.	2 25 W.	Mean of 17 stations by Lake Survey.
Ingham		1829	5 00 E.	1 00 E.	Mean of 11 stations by Land Office.
Ionia		1838	3 33 E.	0 00	Mean of 15 stations by Land Office.
		1895	0 30 E.	0 10 E.	County surveyor.
Iosco		1844	1 50 E.	1 20 W.	Mean of 21 stations by Land Office.
Iron				4 00 E.	Estimated.
Isabella		1839	3 21 E.	0 00	Mean of 15 stations by Land Office.
	Mount Pleasant	1895	0 30 W.	0 50 W.	County surveyor.
Isle Royale		1867	5 24 E.	3 00 E.	Mean of 8 stations by Lake Survey.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Jackson		1828	4 40 E.	0 35 E.	Mean of 17 stations by Land Office.
Kalamazoo		1827	5 23 E.	1 20 E.	Mean of 16 stations by Land Office.
	Kalamazoo	1895	1 32 E.	1 15 E.	Marcus Baker.
Kalkaska		1849	2 48 E.	0 10 W.	Mean of 15 stations by Land Office.
Kent		1837	4 23 E.	0 50 E.	Mean of 24 stations by Land Office.
Keweenaw		1861	5 28 E.	3 00 E.	Mean of 8 stations by Lake Survey.
	Copper Harbor	1873	4 04 E.	2 10 E.	Lake Survey.
	Eagle Harbor	1855	2 40 E.	0 05 W.	Do.
Lake		1839	3 37 E.	0 15 E.	Mean of 15 stations by Land Office.
Lapeer		1826	4 39 E.	0 10 E.	Mean of 17 stations by Land Office.
Leelanaw		1841	3 18 E.	0 00	Mean of 14 stations by Land Office.
	Glen Arbor	1860	3 32 E.	1 00 E.	Lake Survey.
	North Unity	1860	3 32 E.	1 00 E.	Do.
	Good Harbor Island	1860	3 32 E.	1 00 E.	Do.
	Sutton Bay	1860	3 27 E.	1 00 E.	Do.
	North Point	1860	3 30 E.	1 00 E.	Do.
Lenawee		1822	4 48 E.	0 00	Mean of 25 stations by Land Office.
	Adrian	1896	0 14 E.	0 00	County surveyor
Livingston		1829	5 20 E.	1 10 E.	Mean of 9 stations by Land Office.
Luce				0 30 W.	Estimated.
Mackinac		1845	2 58 E.	0 10 W.	Mean of 23 stations by Land Office.
		1854	1 33 E.	1 10 W.	Mean of 18 stations by Lake Survey.
Macomb		1817	4 50 E.	0 10 W.	Mean of 15 stations by Land Office.
Manistee		1842	3 54 E.	0 30 E.	Mean of 18 stations by Land Office.
	Manistee	1866	4 00 E.	1 40 E.	Lake Survey.
Manitou		1847	3 32 E.	0 20 E.	Mean of 6 stations by Land Office.
		1857	3 32 E.	0 55 E.	Mean of 17 stations by Lake Snrvey.
Marquette		1860	5 00 E.	2 25 E.	Mean of 6 stations by Lake Survey.
	Marquette	1873	4 30 E.	2 30 E.	Lake Survey.

County.	Town, city, etc.	Year of observation.	Observed declinations.	Declination in 1900.	Remarks.
			° ′	° ′	
Mason		1838	5 18 E.	1 50 E.	Mean of 17 stations by Land Office.
Mecosta		1841	4 08 E.	0 50 E.	Mean of 15 stations by Land Office.
	Big Rapids	1895	1 18 E.	1 00 E.	County surveyor.
Menominee		1863	4 40 E.	2 20 E.	Mean of 3 stations by Lake Survey.
Midland		1832	3 11 E.	0 50 W.	Mean of 11 stations by Land Office.
Missaukee		1851	3 48 E.	0 50 E.	Mean of 16 stations by Land Office.
Monroe		1827	4 07 E.	0 20 W.	Mean of 22 stations by Land Office.
	Monroe	1895	1 15 W.	0 55 W.	County surveyor.
	Lasalle	1877	0 13 E.	1 20 W.	Lake Survey.
Montcalm		1839	3 33 E.	0 10 E.	Mean of 19 stations by Land Office.
Montmorency		1845	2 27 E.	0 45 W.	Mean of 13 stations by Land Office.
Muskegon		1838	4 19 E.	0 50 E.	Mean of 20 stations by Land Office.
	Muskegon	1871	4 02 E.	1 50 E.	Lake Survey.
	Whitehall	1871	4 02 E.	1 50 E.	Do.
Newaygo		1830	3 35 E.	0 35 W.	Mean of 24 stations by Land Office.
		1837	5 30 E.	2 00 E.	Mean of 2 stations by Lake Survey.
Oakland		1819	4 37 E.	0 25 W.	Mean of 21 stations by Land Office.
	Pontiac	1895	0 28 W.	0 45 W.	County surveyor.
Oceana		1839	4 48 E.	1 30 E.	Mean of 18 stations by Land Office.
	Pentwater	1895	1 45 E.	1 25 E.	County surveyor.
	Benona	1870	4 56 E.	2 45 E.	Lake Survey.
Ogemaw		1845	2 31 E.	0 40 W.	Mean of 16 stations by Land Office.
Ontonagon		1863	8 10 E.	5 45 E.	Mean of 7 stations by Lake Survey.
	Ontonagon	1895	3 00 E.	2 40 E.	County surveyor
Osceola		1842	3 37 E.	0 20 E.	Mean of 16 stations by Land Office.
Oscoda		1840	2 38 E.	0 40 W.	Mean of 16 stations.
Otsego		1840	3 00 E.	0 20 W.	Mean of 15 stations.
Ottawa		1835	5 32 E.	1 50 E.	Mean of 18 stations by Land Office.
	Grand Haven	1880	2 26 E.	1 00 E.	Lake Survey.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Presque Isle		1851	1 59 E.	1 00 W.	Mean of 22 stations by Land Office.
		1859	1 15 E.	1 20 W.	Mean of 4 stations by Lake Survey.
Roscommon		1847	3 00 E.	0 10 W.	Mean of 16 stations by Land Office.
Saginaw		1827	3 12 E.	1 10 W.	Mean of 17 stations by Land Office.
	Saginaw	1876	0 24 E.	1 15 W.	Lake Survey.
St. Clair		1821	4 41 E.	0 20 W.	Mean of 18 stations by Land Office.
		1860	0 30 E.	2 05 W.	Mean of 6 stations by Lake Survey.
	Algonac	1866	0 04 E.	2 15 W.	Lake Survey.
	Fort Gratiot	1873	0 37 W.	1 25 W.	Do.
St. Joseph		1828	5 15 E.	0 55 E.	Mean of 16 stations by Land Office.
Sanilac		1833	3 07 E.	0 50 W.	Mean of 31 stations by Land Office.
		1860	0 55 W.	1 40 W.	Mean of 11 stations by Lake Survey.
	Port Sanilac	1858	0 30 W.	3 10 W.	Lake Survey.
	Forestville	1873	1 30 W.	3 30 W.	Do.
Schoolcraft		1845	4 12 E.	1 00 E.	Mean of 2 stations by Land Office.
		1861	3 30 E.	1 00 E.	Mean of 3 stations by Lake Survey.
Shiawasse		1824	3 21 E.	1 15 W.	Mean of 7 stations by Land Office.
Tuscola		1835	3 50 E.	0 00	Mean of 22 stations by Land Office.
Van Buren		1830	3 50 E.	0 20 W.	Mean of 20 stations by Land Office.
	South Haven	1871	3 30 E.	1 25 E.	Lake Survey.
Washtenaw		1820	4 46 E.	0 15 W.	Mean of 20 stations by Land Office.
	Ann Arbor	1870	0 20 E.	1 50 W.	Lake Survey.
	Ypsilanti	1888	1 30 W.	2 20 W.	Do.
Wayne		1818	4 44 E.	0 15 W.	Mean of 20 stations by Land Office.
	Detroit	1885	0 31 W.	1 35 W.	C. & G. S.
Wexford		1844	3 10 W.	0 00	Mean of 17 stations by Land Office.
	Cadillac	1881	0 22 E.	1 00 W.	County surveyor.

MINNESOTA.

The observations for declination in this State are derived in the main from the work of the General Land Office, and principally from the surveys of standard and exterior lines. Besides these, there are numerous returns from county surveyors and a few from the United States Lake Survey.

The results from the Land Office range in date from 1850 to 1890. They are in the main of good quality, although in the southeastern part of the State there are a number of discrepant counties. While there is undoubtedly a large amount of local attraction in the northeastern part of the State, in the iron ranges, this local attraction is not perceptible in the declination data obtained in those counties. These data have been reduced to the epoch 1900 by the use of corrections set forth in the following table, which have been derived from observations of different dates in the State.

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 45	1860	2 05
1880	1 25	1850	2 40
1870	1 45		

The declination is east, and the above corrections are to be subtracted

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Aitkin		1869	10 05	8 15	Mean of 42 stations.
Anoka		1852	11 37	9 05	Mean of 11 stations.
Becker		1872	12 03	10 25	Do.
Beltrami	North half	1892	9 47	9 20	Mean of 23 stations.
	South half	1889	10 45	10 00	Mean of 48 stations.
Benton		1853	10 46	8 15	Mean of 12 stations.
	Foley	1895	9 10	8 50	County surveyor.
Bigstone		1869	13 00	11 10	Mean of 7 stations.
	Ortonville	1895	10 50	10 30	County surveyor.
Blue Earth		1854	11 12	8 45	Mean of 6 stations.
	Mankato	1894	9 50	9 30	County surveyor.
Brown		1858	10 22	8 00	Mean of 3 stations.
	New Ulm	1895	8 27	8 10	County surveyor
Carlton		1868	9 51	8 00	Mean of 16 stations.
Carver		1858	11 32	9 15	Mean of 7 stations.
Cass	North half	1872	10 40	9 00	Mean of 11 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Cass	South half	1868	10 30	8 40	Mean of 15 stations.
Chippewa		1862	11 33	9 35	Mean of 5 stations.
Chisago		1851	12 03	9 25	Mean of 6 stations.
Clay		1869	12 50	11 00	Mean of 8 stations.
	Glyndon	1880	11 26	10 00	C. & G. S.
Cook		1881	7 50	6 45	Mean of 24 stations.
Cottonwood		1859	11 32	9 20	Mean of 7 stations.
	Windom	1896	9 22	9 10	County surveyor.
Crow Wing		1861	12 16	10 10	Mean of 18 stations.
	Brainerd	1880	9 35	8 10	C. & G. S.
Dakota		1853	9 29	7 00	Mean of 6 stations.
Dodge		1854	8 35	6 10	Mean of 4 stations.
	Mantorville	1895	6 50	6 30	County surveyor.
Douglas		1861	12 50	10 50	Mean of 7 stations.
Faribault		1854	12 27	10 00	Mean of 9 stations.
Fillmore		1853	9 43	7 15	Mean of 12 stations.
	Fountain	1895	7 10	6 55	County surveyor.
Freeborn		1854	9 55	7 30	Mean of 11 stations.
Goodhue		1855	9 04	6 40	Mean of 10 stations.
	Red Wing	1895	6 15	6 00	County surveyor.
Grant		1866	12 36	10 40	Mean of 5 stations.
Hennepin		1854	11 04	8 35	Mean of 7 stations.
	Fort Snelling	1880	10 15	8 50	C. & G. S.
	Minneapolis	1877	10 13	8 40	Do.
Houston		1854	7 54	5 25	Mean of 8 stations.
Hubbard		1875	11 31	10 00	Mean of 6 stations.
Isanti		1856	11 40	9 20	Mean of 14 stations.
Itasca	Northeast quarter	1887	8 47	8 00	Mean of 18 stations.
	Southeast quarter	1875	9 40	8 05	Mean of 43 stations.
	Northwest quarter	1887	9 41	8 50	Mean of 14 stations.
	Southwest quarter	1875	10 45	9 10	Mean of 3 stations.
Jackson		1858	11 41	9 25	Mean of 9 stations.
	Heron Lake	1880	10 15	8 50	C. & G. S.
Kanabec		1855	11 27	9 00	Mean of 15 stations.
Kandiyohi		1857	10 16	8 00	Mean of 6 stations.
Kittson		1874	13 16	11 45	Mean of 11 stations.
Lac qui Parle		1868	12 08	10 15	Mean of 6 stations.
Lake		1882	8 34	7 20	Mean of 27 stations.
Lesueur		1854	11 47	9 15	Mean of 3 stations.
Lincoln		1871	12 08	10 25	Mean of 6 stations.
Lyon		1863	12 00	10 00	Do.
McLeod		1856	11 33	9 05	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Marshall	East half	1881	12 09	10 50	Mean of 4 stations.
	West half	1872	13 50	12 10	Mean of 7 stations.
Martin		1855	10 30	8 00	Mean of 8 stations.
	Welcome	1894	8 50	8 30	County surveyor.
Meeker		1856	11 21	9 00	Mean of 8 stations.
Millelacs		1857	10 31	8 15	Mean of 17 stations.
	Princeton	1858	10 11	7 55	C. & G. S.
Morrison		1855	10 53	8 26	Mean of 24 stations.
Mower		1853	8 30	6 00	Mean of 10 stations.
Murray		1864	11 40	9 45	Mean of 6 stations.
Nicollet		1854	11 03	8 30	Do.
Nobles		1868	11 11	9 20	Mean of 9 stations.
Norman		1874	12 49	11 30	Mean of 14 stations.
Olmstead		1854	9 21	6 55	Mean of 7 stations.
Ottertail		1868	11 58	10 05	Mean of 15 stations.
	Henning	1896	10 05	9 50	County surveyor.
Pine		1859	12 06	9 55	Mean of 21 stations.
Pipestone		1869	11 56	10 05	Mean of 4 stations.
Polk		1877	12 11	10 35	Mean of 31 stations.
Pope		1860	11 05	9 00	Mean of 4 stations.
	Glenwood	1890	11 58	11 15	County surveyor.
Ramsey		1847	11 00	8 10	Mean of 4 stations.
	St. Paul	1890	9 30	8 55	County surveyor.
Redwood		1861	10 31	8 30	Mean of 8 stations.
Renville		1858	11 19	9 05	Mean of 9 stations.
Rice		1854	9 25	7 00	Mean of 5 stations.
Rock		1866	11 21	9 25	Mean of 6 stations.
Rosean		1886	11 43	10 55	Mean of 19 stations.
St. Louis	Northeast quarter	1884	8 09	7 00	Mean of 18 stations.
	Southeast quarter	1871	9 05	7 15	Mean of 21 stations.
	Northwest quarter	1886	8 26	7 25	Mean of 29 stations.
	Southwest quarter	1876	9 14	7 40	Mean of 30 stations.
	Fond du Lac	1861	9 42	7 40	U. S. Lake Survey.
	Duluth	1873	11 52	10 00	Do.
Scott		1854	11 08	8 40	Mean of 6 stations.
Sherburne		1854	10 08	7 40	Do.
Sibley		1853	10 37	8 05	Mean of 11 stations.
	Henderson	1855	11 30	9 00	C. & G. S.
Stearns		1857	10 57	8 40	Mean of 14 stations.
	St. Cloud	1895	8 30	8 15	County surveyor.
Steele		1854	9 18	6 50	Mean of 4 stations.
Stevens		1867	11 26	9 30	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Stevens	Morris	1885	10 46	9 40	County surveyor.
Swift		1865	11 34	9 35	Mean of 7 stations.
Todd		1859	11 14	9 10	Mean of 9 stations.
Traverse		1870	12 14	10 30	Mean of 6 stations.
Wabasha		1855	9 41	7 15	Do.
	Wabasha	1876	8 04	6 30	U. S. Lake Survey.
Wadena		1867	11 12	9 20	Mean of 6 stations.
Waseca		1854	11 32	9 05	Do.
Washington		1847	9 03	6 15	1 station.
Watonwan		1856	10 26	8 00	Mean of 5 stations.
	St. James	1894	9 25	9 05	County surveyor.
Wilkin		1867	13 09	11 15	Mean of 6 stations.
Winona		1854	8 25	6 00	Do.
Wright		1856	11 29	9 10	Mean of 7 stations.
Yellow Medicine		1866	11 32	9 40	Mean of 8 stations.

MISSISSIPPI.

The data for Mississippi are derived almost entirely from the work of the General Land Office, with a few returns from county surveyors and two or three scattering results from other sources.

These results from the General Land Office are from the subdivisional surveys, no plats of exteriors or standard lines being in existence. They bear date from 1810 down to 1850, all being in the first half of the century. In spite of their great age they appear to be of good quality, being consistent among themselves and with observations taken in adjoining States when reduced to a common epoch.

The line of no secular variation appears to have crossed Mississippi just prior to 1830. Most of the Land Office observations are, therefore, complicated with the change of secular variation attendant upon its change of sign. They have been corrected in accordance with the following table, derived from series observed within the State:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1850	2 20
1880	1 00	1840	2 30
1870	1 30	1830	2 30
1860	2 05		

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adams		1846	8 10	5 45	Mean of 6 stations.
	Natchez	1872	7 15	5 50	N. A. S.
Alcorn		1835	7 18	5 50	Mean of 11 stations.
	Corinth	1875	6 22	5 05	N. A. S.
Amite		1813	8 07	5 40	Mean of 19 stations.
	Liberty	1895	6 30	6 15	County surveyor.
Attala		1833	8 00	5 30	Mean of 22 stations.
Benton		1834	7 30	5 00	Mean of 14 stations.
	Ashland	1896	4 40	4 30	County surveyor
Bolivar		1833	8 15	5 45	Mean of 17 stations.
Calhoun		1835	7 45	5 15	Mean of 18 stations.
Carroll		1832	7 57	5 25	Mean of 15 stations.
Chickasaw		1834	7 18	4 50	Mean of 14 stations.
Choctaw		1832	7 56	5 25	Mean of 11 stations.
Claiborne		1846	8 23	6 00	Mean of 6 stations.
Clarke		1833	7 48	5 20	Mean of 20 stations.
Clay		1835	7 46	5 15	Mean of 19 stations.
	West Point	1875	6 25	5 10	N. A. S.
Coahoma		1836	8 12	5 40	Mean of 28 stations.
Copiah		......	....	5 30	Estimated.
Covington		1841	8 20	5 50	Mean of 19 stations.
De Soto		1835	8 00	5 30	Mean of 14 stations.
Franklin		1848	8 56	6 35	Mean of 16 stations.
Greene		1817	8 00	5 45	Mean of 15 stations.
Grenada		1833	7 49	5 20	Mean of 14 stations.
	Grenada	1872	6 25	5 00	N. A. S.
Hancock		1841	7 20	4 50	Mean of 8 stations.
Harrison		1842	7 24	5 00	Mean of 5 stations.
	Long Beach	1895	4 52	4 40	County surveyor.
Hinds	Jackson	1895	5 41	5 25	Do.
Holmes		1833	7 56	5 25	Mean of 11 stations.
Issaquena		......	....	5 50	Estimated.
Itawamba		1835	7 12	4 40	Mean of 14 stations.
Jackson		1845	7 25	5 00	Mean of 8 stations.
	Pascagoula	1875	6 20	5 05	N. A. S.
Jasper		1832	7 50	5 20	Mean of 20 stations.
Jefferson		1848	8 10	5 50	Mean of 9 stations.
Jones		1895	5 00	4 45	County surveyor.
Kemper		1834	7 06	4 35	Mean of 24 stations.
Lafayette		1834	7 43	5 15	Mean of 22 stations.
Lauderdale		1833	7 35	5 05	Mean of 21 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Lauderdale	Meridian	1895	5 04	4 50	County surveyor.
Lawrence		1810	8 29	6 25	Mean of 19 stations.
Leake		1834	8 13	5 45	Mean of 16 stations.
Lee		1834	7 20	4 50	Mean of 10 stations.
Leflore		1833	8 02	5 30	Mean of 19 stations.
Lincoln		1810	8 45	6 40	Mean of 14 stations.
Lowndes		1834	7 38	5 05	Mean of 10 stations.
Madison		1832	8 14	5 45	Mean of 3 stations.
Marion		1827	8 07	5 35	Mean of 39 stations.
Marshall		1834	7 58	5 30	Mean of 24 stations.
Monroe		1836	7 29	5 00	Mean of 12 stations.
Montgomery		1833	8 06	5 35	Do.
	Winona	1896	5 48	5 35	County surveyor.
Neshoba		1833	7 57	5 25	Mean of 14 stations.
Newton		1831	7 43	5 15	Mean of 17 stations.
	Decatur	1895	5 12	5 00	County surveyor.
Noxubee		1833	7 27	5 00	Mean of 20 stations.
	Macon	1833	7 30	5 00	C. & G. S.
Oktibbeha		1832	7 25	4 55	Mean of 12 stations.
Panola		1836	7 52	5 20	Mean of 22 stations.
Pearl River		1893	5 20	5 05	County surveyor.
Perry		1813	8 00	6 00	Mean of 34 stations.
Pike		1810	8 44	6 45	Mean of 20 stations.
Pontotoc		1834	7 13	4 45	Mean of 14 stations.
Prentiss		1835	7 28	4 55	Mean of 9 stations.
Quitman		1842	8 06	5 35	Mean of 11 stations.
Rankin				5 30	Estimated.
Scott		1832	8 00	5 30	Mean of 19 stations.
Sharkey		1837	8 00	5 30	Mean of 2 stations.
Simpson		1896	5 18	5 00	County surveyor.
Smith		1832	7 58	5 30	Mean of 19 stations.
Sunflower		1836	8 11	5 40	Mean of 15 stations.
Tallahatchie		1835	8 00	5 30	Mean of 17 stations.
Tate		1835	8 17	5 45	Mean of 8 stations.
Tippah		1834	7 28	5 00	Mean of 11 stations.
Tishomingo		1835	6 46	4 15	Mean of 20 stations.
Tunica		1836	8 07	5 35	Do.
Union		1834	7 20	4 50	Mean of 9 stations.
Warren		1847	8 23	6 00	Mean of 2 stations.
	Vicksburg	1875	7 20	6 05	N. A. S.
Washington				5 45	Estimated.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Wayne		1817	8 05	6 00	Mean of 6 stations.
Webster		1836	7 52	5 20	Mean of 13 stations.
Wilkinson		1848	8 07	5 45	Mean of 16 stations.
Winston		1833	7 42	5 10	Mean of 17 stations.
Yalobusha		1834	8 07	5 35	Mean of 14 stations.
Yazoo		1837	8 00	5 30	1 station.

MISSOURI.

Observations in Missouri are derived almost exclusively from Professor Nipher's magnetic survey of the State, the results of which have been supplemented to some extent by returns from county surveyors. No attempt has been made in this State to collect data from the General Land Office, since Professor Nipher's results cover most of the counties of the State, and are presumably from data which are of a much better quality than would be furnished by the surveys of the General Land Office; indeed, judging from the known errors in the land surveys in that State, it is to be presumed that the data regarding declinations furnished by these surveys would be misleading.

The quality of the work of Professor Nipher is well known. The observations were taken between the years 1878 and 1882, inclusive, and were published in extenso in the Transactions of the St. Louis Academy of Sciences.

In the county table, where the mean of several results or stations are given for a county it is to be understood that these results are by Nipher's magnetic survey.

The line of no secular variation crossed Missouri between the years 1830 and 1840. The results, therefore, here presented are far removed from the time of no secular variation.

The following table, derived from series of observations, has been used to reduce observations to the epoch 1900:

Year.	Reduction.	Year	Reduction.
	° ′		° ′
1890	0 30	1860	1 40
1880	1 00	1850	2 10
1870	1 15	1840	2 40

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adair	Kirksville	1878	8 29	7 25	Mean of 2 results.
Andrew	Savannah	1895	8 42	8 25	County surveyor.
Atchison	Rockport	1896	10 35	10 20	Do.
Audrain	Mexico	1878	7 44	6 40	Nipher.
Barry		1823	9 40	7 50	Boundary Survey.
Barton		1823	10 15	8 25	Do.
Bates	Rich Hill	1893	8 30	8 10	County surveyor.
Benton	Warsaw	1881	8 51	7 55	Nipher.
	Lincoln	1881	9 19	8 20	Do.
Bollinger	Lutesville	1880	6 14	5 15	Do.
Boone	Columbia	1881	7 24	6 20	Mean of 3 results.
	Centralia	1882	7 57	7 00	Nipher.
	Providence	1881	7 39	6 40	Do.
Buchanan	St. Joseph	1895	8 39	8 25	County surveyor.
Butler	Poplar Bluffs	1880	6 45	5 45	Nipher.
Caldwell	Kingston	1882	9 25	8 30	Mean of 2 results.
Callaway				7 00	Mean of 3 stations.
	McCredie	1881	7 51	6 55	Nipher.
Camden	Linn Creek	1881	9 00	8 00	Do.
	Decaturville	1881	8 57	8 00	Do.
Cape Girardeau				4 50	Estimated.
Carroll	Carrollton	1879	8 30	7 30	Nipher.
Carter				5 30	Estimated.
Cass		1823	10 00	8 10	Boundary Survey.
Cedar				7 45	Estimated.
Chariton				7 15	Do.
Christian				7 00	Do.
Clark		1895	6 05	5 50	County surveyor.
Clay				8 00	Estimated.
Clinton				8 00	Do.
Cole	Jefferson	1880	8 33	7 35	Mean of 2 results.
	Centertown	1881	7 37	6 40	Nipher.
	Marion	1881	7 40	6 45	Mean of 2 results.
Cooper	Clarks Fork	1881	7 29	6 30	Nipher.
	Prairie Home	1881	7 38	6 40	Do.
Crawford	Cuba	1880	7 25	6 25	Do.
Dade	Greenfield	1895	6 15	6 00	County surveyor.
Dallas	Buffalo	1881	8 07	7 10	Nipher.
Daviess		1882	8 46	7 50	Do.
Dekalb	Stewartsville	1896	7 47	7 30	County surveyor.
	Maysville	1882	9 18	8 25	Nipher.
Dent	Salem	1880	6 56	5 55	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Douglas				6 40	Estimated.
Dunklin				5 00	Do.
Franklin				5 30	Mean of 9 stations.
	Washington	1879	6 25	5 20	Mean of 2 results.
	Pacific	1880	7 02	6 00	Do.
	Union	1881	6 35	5 40	Nipher.
	Roedersville	1881	6 56	6 00	Do.
	Newport	1882	6 59	6 00	Do.
Gasconade	Canaan	1895	6 15	6 00	County surveyor.
Gentry	Albany	1882	8 26	7 30	Nipher.
Greene	Springfield	1879	8 36	7 35	Do.
Grundy	Trenton	1882	8 03	7 10	Do.
Harrison	Bethany	1882	8 43	7 50	Do.
Henry	Windsor	1881	8 44	7 45	Do.
Hickory	Wheatland	1881	8 40	7 45	Do.
Holt				8 30	Estimated.
Howard	Glasgow	1879	8 21	7 20	Nipher.
Howell				6 40	Do.
Iron	Arcadia	1880	6 49	5 50	Do.
Jackson	Kansas City	1878	10 18	9 10	Mean of 2 results.
Jasper		1823	10 30	8 40	Boundary Survey.
Jefferson	Desoto	1880	7 46	6 45	Nipher.
	Kimmswick	1880	6 45	5 45	Do.
Johnson				8 10	Mean of 3 stations.
	Holden	1879	8 55	7 55	Nipher.
Knox				6 45	Estimated.
Laclede	Lebanon	1880	7 46	6 45	Mean of 2 results.
Lafayette	Lexington	1896	7 35	7 20	County surveyor.
Lawrence				7 30	Estimated.
Lewis	Canton	1878	7 13	6 05	Nipher.
Lincoln	Troy	1895	5 00	4 45	County surveyor.
Linn				7 25	Mean of 3 stations.
	Linneus	1882	8 03	7 10	Nipher.
	Laclede	1882	8 11	7 20	Do.
Livingston				7 50	Mean of 2 stations.
	Chillicothe	1879	8 32	7 30	Nipher.
McDonald		1823	10 36	8 46	Boundary Survey.
Macon				7 20	Mean of 5 stations.
	Macon	1880	8 03	7 05	Mean of 2 results.
	Mercyville	1882	8 17	7 25	Nipher.
	Laplata	1882	8 09	7 15	Do.
Madison				5 15	Estimated.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Maries	Vienna	1881	7 15	6 20	Nipher.
Marion	Hannibal	1878	7 08	6 00	Do.
	Palmyra	1894	6 03	5 45	County surveyor.
Mercer	Princeton	1882	8 47	7 55	Nipher.
Miller				7 00	Mean of 2 stations.
	Tuscumbia	1881	8 30	7 35	Nipher.
Mississippi	Charleston	1880	5 43	4 45	Do.
Moniteau	California	1881	7 44	6 45	Do.
Monroe				7 15	Mean of 3 stations.
Montgomery				6 35	Mean of 2 stations.
	Danville	1881	7 48	6 50	Nipher.
Morgan				7 15	Mean of 3 stations.
	Versailles	1881	8 20	7 25	Nipher.
New Madrid	Point Pleasant	1850	7 20	5 10	County surveyor.
Newton		1823	10 30	8 40	Boundary Survey.
Nodaway	Maryville	1879	11 10	10 10	Nipher.
Oregon				6 00	Estimated.
Osage				7 00	Mean of 2 stations.
	Linn	1882	7 37	6 45	Nipher.
Ozark				6 30	Estimated.
Pemiscot		1895	5 17	5 00	County surveyor.
Perry		1895	4 45	4 30	Do.
Pettis	Sedalia	1879	8 55	7 50	Mean of 2 results.
Phelps				6 15	Estimated.
Pike	Louisiana	1878	7 07	6 00	Nipher.
Platte				8 30	Estimated.
Polk	Bolivar	1881	8 14	7 15	Nipher.
Pulaski				6 30	Estimated.
Putnam				7 40	Mean of 3 stations.
	Unionville	1882	8 00	7 10	Nipher.
Ralls				6 00	Estimated.
Randolph	Moberly	1882	7 40	6 50	Nipher.
Ray				7 50	Estimated.
Reynolds	West Fork	1895	5 30	5 15	County surveyor.
Ripley				5 50	Mean of 3 stations.
	Doniphan	1894	5 30	5 10	County surveyor.
	Gatewood	1880	7 12	6 10	Nipher.
St. Charles				5 40	Mean of 4 stations.
	St. Charles	1895	4 57	4 40	County surveyor.
	Dardenne Prairie	1881	6 31	5 35	Nipher.
St. Clair				8 00	Estimated.
Ste. Genevieve				5 00	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
St. François				5 15	Estimated.
St. Louis				5 40	Mean of 8 stations.
	Clayton	1881	6 04	5 10	Nipher.
	Pattonsville	1881	5 54	5 00	Do.
	Florissant	1881	6 35	5 40	Do.
	Kirkwood	1882	6 24	5 30	Do.
St. Louis City		1879	6 13	5 10	Do.
Saline	Sweet Springs	1881	9 24	8 30	Do.
	Herndon	1881	8 55	8 00	Do.
	Marshall	1881	8 32	7 35	Do.
	Arrow Rock	1881	7 54	7 00	Do.
Schuyler		1895	8 40	8 25	County surveyor.
Scotland	Memphis	1878	7 48	6 40	Nipher.
Scott				4 50	Estimated.
Shannon		1895	5 15	5 00	County surveyor.
Shelby	Shelbyville	1894	6 20	6 00	Do.
Stoddard		1895	5 00	4 45	Do.
Stone	Cape Fair	1895	5 30	5 15	Do.
Sullivan				7 35	Mean of 4 stations.
	Milan	1895	7 35	7 20	County surveyor.
	Sticklerville	1882	8 52	8 00	Nipher.
Taney	Cedar Creek	1895	6 10	5 55	County surveyor.
Texas	Houston	1880	7 35	6 35	Nipher.
Vernon	Schell	1879	9 03	8 00	Do.
Warren	Warrenton	1882	6 40	5 45	Mean of 2 results.
	Wright	1878	8 14	7 10	Nipher.
Washington				5 30	Estimated.
Wayne	Piedmont	1880	7 22	6 20	Nipher.
Webster				7 00	Estimated.
Worth				8 00	Do.
Wright	Hartville	1895	7 30	7 15	County surveyor.

MONTANA.

Observations in Montana are derived from the surveys of standard lines and township exteriors of the General Land Office, with a few returns from county surveyors, from the Hayden Survey, and from the Mullen and Raynolds expeditions. The Land Office observations appear to be of very good quality.

The line of no secular variation appears to have crossed Montana between the years 1860 and 1880, moving progressively westward, and the observations have been reduced accordingly, using the following table:

Year.	Reductions.		
	Eastern part.	Middle part.	Western part.
	° ′	° ′	° ′
1890	0 40	0 30	0 20
1880	1 10	0 50	0 30
1870	1 25	1 00	0 20
1860	1 40	0 50	0 00

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Beaverhead	Northern	1868	20 30	19 30	1 station.
	Southern	1882	19 36	18 50	Do.
Carbon				18 30	Estimated.
Cascade	Eastern	1882	20 13	19 30	Mean of 2 stations.
	Western	1880	20 30	19 40	Mean of 3 stations.
	Great Falls	1892	20 00	19 40	County surveyor.
	Belt	1894	19 56	19 40	Do.
Chotean	Long. 108–9	1894	19 10	18 50	Mean of 4 stations.
	Long. 109–10	1874	20 40	19 40	Mean of 2 stations.
	Long. 110–11	1867	21 35	20 40	Do.
	Long. 111 to west boundary.	1878	22 00	21 00	Mean of 7 stations.
	Fort Benton	1860	20 24	19 35	Mullan.
Crow Reservation.		1882	18 48	18 00	Mean of 6 stations.
Custer	Lat. 45–6; long. 104–5.			16 00	Estimated.
	Lat. 46 to north boundary; long. 104–5.			16 30	Do.
	Lat. 45–6; long. 105–6.			17 00	Do.
	Lat. 46 to north boundary; long. 105–6.	1884	18 00	17 10	Mean of 5 stations
	Lat. 45–6; long. 106–7.			17 30	Estimated.
	Lat. 46 to north boundary; long. 106 west boundary.	1881	18 40	17 30	1 station.
	Miles	1895	18 00	17 45	County surveyor.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Dawson	Northeastern	1882	17 45	16 45	County surveyor.
	Southeastern	1882	17 45	16 45	Mean of 5 stations.
	Northwestern			17 45	Estimated.
	Southwestern			18 00	Do.
Deer Lodge		1881	20 24	19 50	Mean of 6 stations.
Fergus	Northeastern	1882	19 35	18 50	Mean of 3 stations.
	Southeastern	1882	19 42	19 00	Mean of 6 stations.
	Northwestern	1883	19 43	19 00	Mean of 2 stations.
	Southwestern	1882	18 30	17 45	1 station.
Flathead	Eastern	1892	22 06	21 50	Mean of 32 stations.
	Western	1893	22 20	22 10	Mean of 8 stations.
Gallatin	Northern	1872	19 20	18 20	Do.
	Southern	1872	19 10	18 10	1 station.
Granite	Phillipsburg	1895	20 30	20 20	County surveyor.
Jefferson		1868	20 50	19 50	Mean of 4 stations.
Lewis and Clarke.	Northern			20 30	Estimated.
	Southern	1873	20 43	19 50	Mean of 5 stations.
	Helena	1872	20 00	19 05	Hayden.
Madison	Northern	1871	19 25	18 20	Do.
	Southern			18 30	Estimated.
	Virginia	1895	19 15	19 00	County surveyor.
Meagher	Eastern			19 00	Estimated.
	Western	1875	20 00	19 00	Mean of 8 stations.
Missoula	Eastern	1882	22 00	21 30	Mean of 13 stations.
	Western	1860	20 45	20 45	1 station.
	Fort Owen	1853	19 25	19 25	Raynolds.
	Hell Gate	1861	21 00	21 00	Mullan.
	Bitterroot	1860	20 45	20 45	Do.
Park	Northern			18 30	Estimated.
	Southern	1882	19 00	18 10	1 station.
Ravalli		1893	20 20	20 10	Mean of 10 stations.
Silver Bow		1868	20 10	19 55	1 station.
Sweetgrass				18 30	Estimated.
Teton	Northeastern	1881	21 43	21 00	Mean of 5 stations.
	Southeastern	1892	21 10	20 50	Mean of 2 stations.
	Northwestern	1874	23 25	22 25	Mean of 5 stations.
Valley	Long. 104–5	1866	18 27	17 00	Mean of 6 stations.
	Long. 105–6	1873	19 50	18 30	Do.
	Long. 106–7	1874	20 17	19 00	Do.
	Long. 107–8	1884	20 00	19 10	Mean of 8 stations.
Yellowstone	Northeastern	1881	19 23	18 35	Mean of 3 stations.
	Northwestern	1883	19 13	18 20	Mean of 6 stations.

NEBRASKA.

Observations in Nebraska are derived mainly from the surveys of standard lines and exteriors of the General Land Office. Numerous returns have been received from county surveyors, and to these have been added a few stations by the United States Coast and Geodetic Survey and other miscellaneous sources. Surveys of the General Land Office range in time from 1855 in the eastern part of the State to very recent years in the western part. They appear to be throughout of good quality, although much better in the western part of the State than in the eastern. The line of no secular variation crossed Nebraska between the years 1845 and 1860. Observations in the eastern part of the State are, therefore, in the reduction to 1900, somewhat complicated with the change in secular variation. They have been reduced to the epoch 1900 in accordance with the following table, derived from series of observations made in the State:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1860	1 55
1880	1 15	1850	2 00
1870	1 50		

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adams		1875	12 35	11 00	Mean of 16 stations.
	Hastings	1895	10 15	9 55	County surveyor.
Antelope		1858	13 05	11 10	Mean of 14 stations.
Arthur		1869	14 21	12 30	Mean of 5 stations.
Banner		1870	15 47	14 00	Mean of 4 stations.
	Ashford	1895	14 30	14 10	County surveyor.
Blaine		1872	13 24	11 45	Mean of 4 stations.
Boone		1858	12 42	10 35	Mean of 5 stations.
Boxbutte		1880	14 35	13 20	Mean of 16 stations.
Boyd				11 50	Estimated.
Brown		1874	13 35	12 00	Mean of 28 stations.
Buffalo		1860	14 04	12 10	Mean of 16 stations.
	Kearney	1858	13 38	11 45	Simpson.
Burt		1856	12 05	10 05	Mean of 8 stations.
Butler		1857	12 02	10 00	Mean of 12 stations.
Cass		1856	10 45	8 50	Mean of 3 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Cass	Plattsmouth	1895	9 30	9 10	County surveyor.
Cedar		1858	12 12	10 15	Mean of 12 stations.
Chase		1870	13 46	12 00	Mean of 14 stations.
Cherry	East half	1875	13 35	12 00	Mean of 24 stations.
	West half	1880	14 35	13 20	Mean of 30 stations.
Cheyenne		1870	15 00	13 10	Mean of 16 stations.
	Camp Clark	1896	13 30	13 15	County surveyor.
	Sidney	1872	14 37	12 50	N. A. S.
Clay		1858	12 19	10 20	Mean of 12 stations.
Colfax		1857	12 20	10 20	Mean of 3 stations.
Cuming		1857	12 21	10 20	Mean of 7 stations.
Custer		1872	13 22	11 35	Mean of 41 stations.
Dakota		1857	12 19	10 20	Mean of 5 stations.
Dawes		1882	15 13	14 05	Mean of 41 stations.
Dawson		1869	13 39	11 50	Mean of 18 stations.
Deuel		1869	14 35	12 50	Mean of 12 stations.
Dixon		1857	12 36	10 35	Mean of 3 stations.
Dodge		1856	11 48	9 50	Mean of 9 stations.
Douglas		1856	10 53	8 55	Mean of 5 stations.
	Omaha	1888	9 30	8 40	C. & G. S.
Dundy		1870	13 53	12 05	Mean of 9 stations.
Fillmore		1858	12 26	10 25	Mean of 12 stations.
Franklin		1858	13 15	11 20	Mean of 8 stations.
Frontier		1870	14 13	12 20	Mean of 16 stations.
Furnas		1870	14 25	12 35	Mean of 9 stations.
Gage		1856	9 47	7 45	Mean of 6 stations
	Beatrice	1895	11 00	10 40	County surveyor.
Garfield		1870	13 20	11 30	Mean of 12 stations.
Gosper		1865	14 33	12 35	Mean of 8 stations.
Grant		1876	13 55	12 20	Mean of 16 stations.
Greeley		1863	12 38	10 45	Mean of 8 stations.
Hall		1862	13 20	11 25	Mean of 12 stations.
	Grand Island	1893	11 51	11 20	City surveyor.
Hamilton		1858	12 42	10 40	Mean of 10 stations.
Harlan		1865	13 18	11 25	Mean of 8 stations.
Hayes		1870	13 21	11 35	Mean of 14 stations.
Hitchcock		1870	13 22	11 30	Mean of 9 stations.
	Culbertson	1895	12 10	11 50	County surveyor.
Holt		1865	13 39	11 50	Mean of 31 stations.
Hooker		1875	13 45	12 10	Mean of 16 stations.
Howard		1862	13 56	12 00	Mean of 8 stations.
Jefferson		1856	12 13	10 15	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Jefferson	Fairbury	1895	9 48	9 30	County surveyor.
Johnson		1856	10 00	8 00	Mean of 7 stations.
Kearney		1858	13 51	11 50	Mean of 8 stations.
Keith		1869	14 20	12 30	Mean of 13 stations.
Keyapaha		1872	14 07	12 20	Mean of 2 stations.
Kimball		1870	15 29	13 40	Mean of 12 stations.
Knox		1858	13 16	11 15	Mean of 13 stations.
Lancaster		1857	10 08	8 10	Mean of 14 stations.
Lincoln		1869	13 41	11 50	Mean of 35 stations.
Logan		1869	13 36	11 45	Mean of 4 stations.
Loup		1872	13 25	11 45	Mean of 8 stations.
McPherson		1869	13 47	12 00	Mean of 6 stations.
Madison		1858	12 47	10 50	Mean of 12 stations.
Merrick		1858	13 15	11 20	Mean of 5 stations.
Nance		1858	13 12	11 15	Mean of 7 stations.
Nemaha		1855	11 10	9 10	Do.
	Brownville	1877	11 15	9 55	C. & G. S.
	Auburn	1896	10 10	9 55	County surveyor.
	Peru	1888	10 13	9 30	C. & G. S.
Nuckolls		1858	12 45	10 40	Mean of 8 stations.
Otoe		1856	10 17	8 10	Mean of 9 stations.
	Nebraska City	1880	10 13	9 00	Mo. River Com.
Pawnee		1856	10 19	8 20	Mean of 6 stations.
Perkins		1870	13 13	11 25	Mean of 10 stations.
Phelps		1865	13 53	12 00	Mean of 8 stations.
	Holdrege	1896	12 23	12 10	County surveyor.
Pierce		1858	12 36	10 40	Mean of 12 stations.
	Plainview	1895	8 43	8 30	County surveyor.
Platte		1857	12 55	10 55	Mean of 13 stations.
	Columbus	1895	10 32	10 15	County surveyor.
Polk		1858	12 30	10 30	Mean of 8 stations.
Redwillow		1870	13 12	11 25	Mean of 5 stations.
Richardson		1855	12 00	10 00	Mean of 31 stations.
Rock		1865	13 45	11 55	Mean of 7 stations.
Saline		1857	11 36	9 35	Mean of 8 stations.
Sarpy		1856	10 53	8 55	Mean of 5 stations.
	Papillion	1895	9 48	9 30	County surveyor.
Saunders		1857	11 36	9 35	Mean of 13 stations.
Scotts Bluff		1879	15 25	14 10	Mean of 18 stations.
Seward		1857	11 39	9 40	Mean of 12 stations.
Sheridan		1881	14 48	13 40	Mean of 29 stations.
Sherman		1868	13 44	11 55	Mean of 12 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Sioux		1882	15 20	14 15	Mean of 34 stations.
Stanton		1857	12 16	10 15	Mean of 10 stations.
Thayer		1858	12 45	10 50	Mean of 8 stations.
Thomas		1874	13 42	12 10	Mean of 20 stations.
Thurston		1856	12 06	10 05	Mean of 9 stations.
Valley		1867	12 18	10 30	Mean of 12 stations.
Washington		1856	10 34	8 35	Mean of 4 stations.
Wayne		1857	12 17	10 20	Mean of 8 stations.
Webster		1867	12 33	10 45	Mean of 12 stations.
Wheeler		1865	12 40	10 50	Do.
York		1858	12 33	10 35	Do.

NEVADA.

The observations in Nevada consist almost entirely of results from the General Land Office, with a few from the Coast and Geodetic Survey, from the Wheeler Survey, and from county surveyors. The Land Office observations are derived exclusively from the surveys of standard lines and township exteriors.

The line of no secular variation crossed Nevada between the years 1880 and 1890. These observations have been reduced to the epoch 1900 in accordance with this fact by means of the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	−0 15	1870	0 00
1880	−0 15	1860	+0 25

The declination is east. Such of the above corrections as have the plus sign are to be added and those having the minus sign subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Churchill	Eastern	1872	17 30	17 30	Mean of 6 stations.
	Western	1875	17 20	17 20	Do.
	Hot Springs	1881	17 26	17 10	C. & G. S.
Douglas		1869	16 14	16 15	Mean of 13 stations.
	Genoa	1877	16 47	16 35	Wheeler.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Douglas	Glenbrook	1876	16 00	15 50	Wheeler.
Elko	Northeastern	1881	17 53	17 40	Mean of 8 stations.
	Southeastern	1881	17 00	16 45	Mean of 12 stations.
	North middle	1887	17 30	17 15	Mean of 16 stations.
	South middle	1880	16 50	16 35	Mean of 12 stations.
	Northwestern	1883	17 44	17 30	Mean of 3 stations.
	Southwestern	1880	17 30	17 15	Mean of 2 stations.
	Elko	1881	17 30	17 15	C. & G. S.
	Halleck	1869	16 22	16 20	Wheeler.
Esmeralda	Northern	1880	16 46	16 30	Mean of 19 stations.
	Middle	1883	17 00	16 45	Mean of 7 stations.
	Southern	1877	16 25	16 15	Mean of 9 stations
	Dead Horse Well	1876	16 30	16 20	Wheeler.
	Hawthorne	1887	16 28	16 15	County surveyor.
	Silver Peak	1890	16 08	15 55	Do.
Eureka	Northern	1873	16 53	16 55	Mean of 9 stations.
	Southern	1879	16 37	16 20	Mean of 15 stations.
	Eureka	1881	16 37	16 20	C. & G. S.
	Mineral Hill	1881	17 03	16 50	Do.
Humboldt	Northeastern	1878	17 45	17 30	Mean of 60 stations.
	Southeastern	1874	17 44	17 30	Mean of 22 stations.
	Northwestern	1874	17 40	17 30	Do.
	Southwestern	1880	17 25	17 10	Mean of 13 stations.
	Ryepatch	1881	17 50	17 35	C. & G. S.
	Winnemucca	1881	17 40	17 25	Do.
	Wells	1881	17 22	17 10	Do.
	Tecoma	1881	17 28	17 15	Do.
Lander	Northern	1870	17 35	17 35	Mean of 95 stations.
	Southern	1874	16 42	16 35	Mean of 97 stations.
	Austin	1881	16 57	16 40	C. & G. S.
Lincoln	Northern	1874	16 10	16 00	Mean of 20 stations.
	Middle eastern	1881	16 20	16 05	Mean of 13 stations.
	Middle western	1870	16 08	16 10	Mean of 6 stations.
	Southeastern	1877	15 34	15 24	Mean of 15 stations.
	Southwestern	1878	15 46	15 30	Mean of 17 stations.
	Southern point	1878	15 22	15 10	Mean of 4 stations.
	Clover Valley	1869	14 25	14 25	Wheeler.
	St. Thomas	1869	15 48	15 48	Do.
	Indian Spring	1869	15 42	15 40	Do.
	West Point	1869	15 42	15 40	Do.
	Mouth of Rio Virgin.	1869	15 48	15 50	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Lincoln	Pioche	1892	16 00	15 50	County surveyor.
	Stone Ferry	1875	15 00	14 50	Wheeler.
Lyon		1868	16 42	16 40	Mean of 18 stations.
Nye	Northeastern	1875	16 25	16 15	Mean of 8 stations.
	North middle	1874	16 05	15 55	Mean of 17 stations.
	Northwestern	1875	16 35	16 25	Mean of 15 stations.
	Central			16 15	Estimated.
	Southern			15 30	Do.
Ormsby		1865	16 13	16 25	Mean of 4 stations.
	Carson	1876	16 47	16 35	Wheeler.
Storey		1861	16 35	17 00	Mean of 3 stations.
	American Flat	1876	16 30	16 20	Wheeler.
Washoe	Northern	1878	18 26	18 15	Mean of 6 stations.
	Middle	1882	17 36	17 20	Mean of 4 stations.
	Southern	1868	16 55	17 00	Mean of 40 stations.
	Reno	1881	17 50	17 35	C. & G. S.
	Verdi	1889	17 26	17 10	Do.
White Pine	Northeastern	1868	16 42	16 40	Mean of 8 stations.
	Southeastern	1871	16 30	16 30	Mean of 17 stations.
	Northwestern	1868	16 46	16 50	Mean of 18 stations.
	Southwestern	1872	16 34	16 35	Mean of 29 stations.
	Hamilton	1869	16 43	16 40	Wheeler.
	Rattlesnake Spring.	1869	16 18	16 20	Do.
	Sacramento district.	1869	16 27	16 30	Do.
	Monte Cristo	1869	17 05	17 05	Do.
	Antelope Springs	1869	17 00	17 00	Do.
	Piermont	1872	16 45	16 45	Do.
	Long Valley	1869	17 00	17 00	Do.
	Old Camp Ruby	1869	17 10	17 10	Do.

NEW HAMPSHIRE.

Data for New Hampshire have been taken almost exclusively from the Coast Survey compilation, consisting of observations by the United States Coast and Geodetic Survey and observations accredited to the Royal Society and the Smithsonian Institution.

Wherever in the county table the mean of several stations is given for the county, it is understood to include those stations which are given subsequently separately.

The earliest observation used here bears date 1830, and since the line of no secular variation crossed New Hampshire prior to the beginning of the century, none of these observations are complicated with the change in secular variation. Corrections for secular variation have been used to reduce these observations to the epoch 1900, as deduced from observations in this State, Vermont, Massachusetts, Rhode Island, and Connecticut. The following table shows the reductions:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 20	1850	2 55
1880	0 45	1840	3 40
1870	1 25	1830	4 40
1860	2 05	1820	5 20

The declination is west, and the correction for the secular variation is to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Belknap				13 00	Mean of 2 stations.
Carroll				14 00	Estimated.
Cheshire				11 50	Mean of 4 stations.
	Troy	1861	9 04	11 05	C. & G. S.
	Chesterfield	1891	11 30	11 50	County surveyor.
Coos	Gorham	1873	13 47	15 00	C. &. G. S.
	Fabyans	1845	11 32	14 50	Smithsonian Contributions.
Grafton	Hanover	1895	11 56	12 05	Dartmouth Observatory.
	Littleton	1873	13 00	14 15	C. & G. S.
	West Romney	1830	9 38	14 20	Royal Society.
	Warren	1830	9 08	13 50	Do.
	Haverhill	1830	7 32	12 10	Do.
	Lyman	1879	11 33	12 20	Do.
Hillsboro				12 25	Mean of 2 stations.
Merrimack	Concord	1879	11 27	12 15	C. & G. S.
Rockingham				13 40	Mean of 5 stations.
	Portsmouth	1844	9 46	13 10	Royal Society.
	Plymouth	1830	8 32	13 10	Do.
Strafford				13 30	Estimated.
Sullivan	Claremont	1896	12 29	12 35	County surveyor.

NEW JERSEY.

The data in New Jersey are derived mainly from volume 1 of the final report of the Geological Survey of that State. The results therein contained are in part from observations made by the New Jersey Geological Survey and in part were compiled by it. They are, with one or two exceptions, of recent date, being taken subsequent to 1880, and are of excellent quality.

For the reduction of these observations to the epoch 1900, corrections derived from the series observed in New York, New Jersey, and Pennsylvania have been applied. The following table of reductions applies to observations in this State:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 25	1840	3 20
1880	0 55	1830	4 15
1870	1 45	1820	4 50
1860	2 20	1810	5 05
1850	2 55		

The declination is west, and the reductions for secular variation are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Atlantic				6 35	Mean of 5 stations.
	Atlantic City	1887	6 22	6 55	N. J. Geol. Survey.
	Hammonton	1885	5 53	6 35	Do.
	Lays Landing	1887	5 52	6 25	Do.
Bergen				9 15	Mean of 16 stations.
	Englewood	1887	8 29	9 05	N. J. Geol. Survey.
	Fairlawn	1887	8 06	8 40	Do.
	Hackensack	1887	7 49	8 25	Do.
	Mahwah	1887	8 23	9 00	Do.
Burlington				7 25	Mean of 16 stations.
	Bass River	1885	6 30	7 10	N. J. Geol. Survey.
	Bordentown	1885	7 03	7 45	Do.
	Brown's Mills	1885	6 53	7 35	Do.
	Ellisdale	1885	6 45	7 25	Do.
	Columbus	1885	7 15	7 55	Do.
	Little Egg Harbor.	1846	4 28	7 35	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Burlington	Mount Holly	1887	6 51	7 25	N. J. Geol. Survey.
	Shamong	1887	6 36	7 10	Do.
	Smithville	1885	6 32	7 10	Do.
	Tuckerton	1887	6 52	7 25	Do.
Camden				6 40	Mean of 7 stations.
	Berlin	1885	5 32	6 10	N. J. Geol. Survey.
	Camden	1887	6 10	6 45	Do.
	Haddonfield	1887	6 10	6 45	Do.
	Waterford	1885	5 49	6 30	Do.
	Winslow	1887	5 57	6 30	Do.
Cape May				6 05	Mean of 4 stations.
	Cape May	1887	5 11	5 45	N. J. Geol. Survey.
	Oceanview	1887	5 40	6 15	Do.
Cumberland				6 05	Mean of 11 stations.
	Bridgeton	1887	5 19	5 55	N. J. Geol. Survey.
	Greenwich	1846	3 14	6 25	Do.
	Port Norris	1887	5 24	6 00	Do.
Essex				8 35	Mean of 6 stations.
	Cooks Bridge	1887	8 02	8 35	N. J. Geol. Survey.
	Livingston	1887	8 10	8 45	Do.
	Orange	1887	8 05	8 40	Do.
	Newark	1887	7 49	8 25	Do.
Gloucester				6 30	Mean of 4 stations.
	Clayton	1885	5 46	6 25	N. J. Geol. Survey.
	Newfield	1887	5 45	6 20	Do.
	Woodbury	1887	6 02	6 35	Do.
Hudson				9 20	Mean of 5 stations.
	Jersey City	1871	7 55	9 35	N. J. Geol. Survey.
	Harrison	1887	7 49	8 25	Do.
	Secaucus	1887	8 45	9 20	Do.
	West Hoboken	1887	8 55	9 30	Do.
Hunterdon				7 45	Mean of 15 stations.
	Flemington	1887	7 14	7 50	N. J. Geol. Survey.
	Frenchtown	1887	7 10	7 45	Do.
	Glen Gardner	1887	6 59	7 35	Do.
	Highbridge	1887	8 18	8 50	Do.
	Lambertville	1887	6 55	7 30	Do.
	Lebanon	1887	6 53	7 30	Do.
	Pattenburg	1887	6 53	7 30	Do.
	Valley	1887	7 04	7 40	Do.
Mercer				7 45	Mean of 5 stations.

County.	Town, city, etc	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Mercer	Hamilton Square	1885	6 58	7 40	N. J. Geol. Survey.
	Hightstown	1887	7 18	7 55	Do.
	Princeton	1887	7 09	7 45	Do.
	Trenton	1887	7 13	7 50	Do.
Middlesex				8 10	Mean of 7 stations.
	Jamesburg	1887	7 25	8 00	N. J. Geol. Survey.
	New Brunswick	1887	7 34	8 10	Do.
	Perth Amboy	1885	7 43	8 25	Do.
Monmouth				8 00	Mean of 9 stations.
	Freehold	1887	7 15	7 50	N. J. Geol. Survey.
	Morganville	1887	7 35	8 10	Do.
	Redbank	1887	7 23	8 00	Do.
	Sandy Hook	1885	7 53	8 35	Do.
	Seabright	1884	7 12	7 55	Do.
	Seagirt	1884	6 59	7 40	Do.
Morris				8 45	Mean of 29 stations.
	Boonton	1887	8 05	8 40	N. J. Geol. Survey.
	Chester	1887	7 56	8 30	Do.
	Dover	1887	8 58	9 35	Do.
	Gillette	1887	7 53	8 30	Do.
	Hanover	1887	8 00	8 35	Do.
	Lake Hopatcong	1884	8 15	9 00	Do.
	Morristown	1887	9 00	9 35	Do.
	Newfoundland	1887	7 58	8 35	Do.
Ocean				7 40	Mean of 6 stations.
	Barnegat	1887	6 52	7 25	N. J. Geol. Survey.
	Long Beach	1860	5 18	7 40	Do.
	New Egypt	1887	6 56	7 30	Do.
	Seaside Park	1887	6 56	7 30	Do.
	Whitings	1887	7 09	7 45	Do.
Passaic				8 55	Mean of 8 stations.
	Paterson	1887	8 00	8 35	N. J. Geol. Survey.
	Pompton	1887	9 16	9 50	Do.
Salem				6 40	Mean of 4 stations.
	Salem	1887	5 42	6 15	N. J. Geol. Survey.
Somerset				8 05	Mean of 7 stations.
	Blawenburg	1887	7 36	8 10	N. J. Geol. Survey.
	Middlebush	1887	7 13	7 55	Do.
	Somerville	1887	7 22	7 55	Do.
Sussex				7 45	Mean of 33 stations.
	Deckertown	1884	7 29	8 05	N. J. Geol. Survey.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Sussex	Hamburg	1882	7 04	8 00	N. J. Geol. Survey.
	Layton	1887	7 25	8 00	Do.
	Montague	1887	7 21	7 55	Do.
	Monroe Corner ..	1887	7 03	7 40	Do.
	Newton	1887	7 21	7 55	Do.
	Unionville	1887	6 15	6 50	Do.
Union..........	....	......	....	8 25	Mean of 3 stations.
	Plainfield	1887	7 40	8 15	N. J. Geol. Survey.
Warren	....	......	....	7 25	Mean of 18 stations.
	Allamuchy	1887	8 18	8 50	N. J. Geol. Survey.
	Blairstown.......	1887	7 25	8 00	Do.
	Hackettstown ...	1887	6 50	7 25	Do.
	Hardwick........	1886	7 11	7 50	Do.
	Phillipsburg	1887	6 10	6 45	Do.
	Warrenville......	1881	6 00	6 50	Do.

NEW MEXICO.

Observations in New Mexico have, as everywhere else in the Land Office States and Territories, been derived mainly from the surveys of the General Land Office. In the case of this Territory, they come almost exclusively from the surveys of standard lines and township exteriors. A few results are included from the Wheeler and one from Lieutenant Ives's expedition. The Land Office work is of excellent quality in this Territory, being mainly of date subsequent to 1880.

The line of no secular variation crossed New Mexico between 1860 and 1865, and the results have been corrected by the use of the following table, derived from series in Colorado, modified to accord with the southward flattening of the curve of secular variation.

Year.	Reduction.	
	Eastern part.	Western part.
	° ′	° ′
1890..	0 35	0 30
1880..	1 00	0 50
1870..	1 15	1 00
1860..	1 25	1 00

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Bernalillo	Eastern	1881	13 06	12 20	Mean of 45 stations.
	Middle	1882	13 30	12 45	Mean of 37 stations.
	Western	1881	13 42	13 00	Mean of 23 stations.
	Albuquerque	1888	13 10	12 35	C. & G. S.
	Isleta	1854	13 13	12 20	Ives.
	Fort Wingate	1873	14 52	14 00	Wheeler.
Chaves	Northeastern	1882	12 13	11 20	Mean of 65 stations.
	Southeastern	1882	11 28	10 35	Mean of 24 stations.
	Northwestern	1881	12 30	11 35	Mean of 49 stations.
	Southwestern	1880	12 16	11 20	Mean of 42 stations.
Colfax	Eastern	1882	13 33	12 40	Mean of 16 stations.
	Western	1881	13 27	12 30	Mean of 3 stations.
Donna Ana	Northeastern	1882	12 28	11 45	Mean of 36 stations.
	Southeastern	1880	12 27	11 40	Mean of 40 stations.
	Western	1883	12 25	11 40	Mean of 57 stations.
Eddy	Northeastern	......	....	10 40	Estimated.
	Southeastern	1884	11 32	10 45	Mean of 10 stations.
	Northwestern	1882	11 54	11 00	Mean of 32 stations.
	Southwestern	1883	12 00	11 05	Mean of 36 stations.
Grant	Northeastern	1883	12 37	11 50	Mean of 16 stations.
	Southeastern	1886	12 21	11 40	Mean of 22 stations.
	Northwestern	1883	12 33	11 50	Mean of 43 stations.
	Southwestern	1883	12 21	11 40	Mean of 34 stations.
	Deming	1888	12 46	12 10	C. & G. S
	Fort Bayard	1878	12 56	12 00	Wheeler.
Guadaloupe	Northeastern	1879	12 24	11 20	Mean of 31 stations.
	Southeastern	1882	12 18	11 20	Mean of 45 stations.
	Northwestern	1871	12 52	11 40	Mean of 35 stations.
	Southwestern	1880	12 36	11 30	Mean of 21 stations.
Lincoln	Northeastern	1882	12 34	11 40	Mean of 40 stations.
	Southeastern	1884	12 43	12 00	Mean of 5 stations.
	East middle	1880	12 22	11 30	Mean of 30 stations.
	West middle	1873	12 40	11 45	Mean of 7 stations.
	Northwestern	1881	12 42	11 50	Mean of 21 stations.
	Southwestern	1884	12 06	11 25	Mean of 11 stations.
Mora	Eastern	1881	13 23	12 30	Mean of 28 stations.
	Western	1882	13 42	12 50	Mean of 5 stations.
Rio Arriba	Northeastern	1882	13 47	13 00	Mean of 18 stations.
	Southeastern	1882	13 34	12 45	Mean of 26 stations.
	Northwestern	1882	13 13	12 35	Mean of 21 stations.
	Southwestern	1882	13 00	12 15	Mean of 9 stations.
	Embudo	1874	13 15	12 20	Wheeler.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Rio Arriba	Abiquiu	1874	13 54	13 00	Whee
	Tierra Amarilla	1873	13 43	12 50	Do.
San Juan	Northeastern	1881	13 12	12 25	Mean of 32 stations.
	Southeastern	1882	13 02	12 15	Mean of 21 stations.
	Northwestern	1881	13 36	12 45	1 station.
	Southwestern	......	....	13 00	Estimated.
San Miguel	Eastern	1877	12 52	11 45	Mean of 5 stations.
	Middle	1878	13 02	11 55	Mean of 24 stations.
	Western	1875	13 15	12 10	Mean of 38 stations.
Santa Fe	Northern	1883	13 30	12 30	Mean of 8 stations.
	Southern	1876	13 18	12 00	Mean of 13 stations.
	Santa Fe	1886	12 55	12 05	C. & G. S.
Sierra	Northern	1882	12 50	12 05	Mean of 49 stations.
	Southern	1885	12 48	12 08	Mean of 15 stations.
Socorro	Northeastern	1869	12 53	11 30	Mean of 21 stations.
	Southeastern	1881	12 18	11 10	Mean of 50 stations.
	North middle	1881	13 13	12 10	Mean of 85 stations.
	South middle	1882	12 43	11 45	Mean of 48 stations.
	Northwestern	1882	13 18	12 20	Mean of 71 stations.
	Southwestern	1884	12 58	12 10	Mean of 56 stations.
	Fort Craig	1888	12 26	11 45	C. & G. S.
Taos	....	1881	13 27	12 30	Mean of 20 stations.
Union	Northern	1880	12 34	11 45	Mean of 21 stations.
	Southern	1880	12 30	11 40	Mean of 57 stations.
Valencia	Long. 105–106	1881	12 35	11 45	Mean of 44 stations.
	Long. 106–107	1879	12 33	11 45	Mean of 22 stations.
	Long. 107–108	1881	13 20	12 30	Mean of 48 stations.
	Long. 108–109	1882	13 28	12 50	Mean of 62 stations.

NEW YORK.

The observations in New York are derived from various sources, the United States Coast and Geodetic Survey, the United States Lake Survey, the New York State Survey, Geological Survey of New York, Adirondack Survey, and county and city surveyors. They bear various dates, ranging from 1821 down to the present time.

Wherever in the county table the mean of several stations is given for the county, it is understood to include the stations which are given individually.

The line of no secular change apparently crossed New York about the beginning of the century. The earliest of these observations are therefore scarcely, if at all, affected by the change in secular variation, and corrections have been applied to them to reduce them to the epoch 1900, as derived from the series in this State, New Jersey, and Pennsylvania. These corrections are set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 25	1840	3 20
1880	0 55	1830	4 15
1870	1 45	1820	4 50
1860	2 20	1810	5 05
1850	2 55		

The declination is west, and the reductions for secular variation are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Albany				10 15	Mean of 9 stations.
	Albany	1879	9 52	10 50	C. & G. S.
Allegany				5 50	Mean of 3 stations.
	Belmont	1895	5 30	5 45	County surveyor.
Broome	Binghamton	1895	7 50	8 00	Do.
Cattaraugus				5 45	Mean of 3 stations.
	Ellicottville	1841	2 36	5 55	C. & G. S.
Cayuga				8 05	Mean of 3 stations.
	Auburn	1833	3 13	7 40	Geol. Survey, N. Y.
Chautauqua				4 05	Mean of 4 stations.
	Mayville	1874	2 25	3 50	N. A. S.
	Westfield	1875	3 18	4 40	U. S. Lake Survey.
	Dunkirk	1845	1 12	4 20	Do.
	Fredonia	1895	4 50	5 00	County surveyor.
Chemung				7 30	Estimated.
Chenango				8 35	Mean of 3 stations.
	Oxford	1885	7 13	8 25	C. & G. S.
	Sherburne	1875	7 50	9 10	Do.
Clinton				13 40	Mean of 9 stations.
	Rouse Point	1879	13 40	14 40	C. & G. S.
	Plattsburg	1870	10 52	12 35	U. S. Lake Survey.
	West Chazy	1838	9 20	12 50	Silliman's Journal.
	Champlain	1838	9 30	13 00	Adirondack Survey.
Columbia				10 10	Mean of 3 stations.
	Ancram	1853	7 40	10 25	Geol Survey, N. Y.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Columbia	Livingston	1888	9 30	10 00	C. & G. S.
	Hudson	1888	9 30	10 00	Do.
Cortland	Homer	1840	5 05	8 25	Geol. Survey, N. Y.
Delaware				9 00	Mean of 2 stations.
	Loomis	1882	8 10	9 00	C. & G. S.
Dutchess	Madalin	1878	8 45	9 50	Do.
Erie				5 20	Mean of 6 stations.
	Buffalo	1885	5 00	5 40	County surveyor.
	Fort Erie	1839	1 15	4 40	U. S. Lake Survey.
	Grand Island	1875	3 00	4 20	Do.
	Tonawanda	1875	3 50	5 10	Do.
Essex				12 00	Mean of 14 stations.
	Lewis	1895	12 56	13 10	County surveyor.
	Crown Point	1879	9 35	10 35	Adirondack Survey.
	Keene Valley	1883	11 32	12 20	Do.
	Keeseville	1838	8 40	12 10	Silliman's Journal.
Franklin				11 25	Mean of 7 stations.
	Upper Saranac Lake.	1883	10 45	11 30	Adirondack Survey.
	St. Regis lakes	1883	10 10	10 55	Do.
	Malone	1883	12 30	13 15	Do.
	St. Regis	1883	10 30	11 15	Do.
Fulton	Johnstown	1818	6 00	10 55	Geol. Survey, N. Y.
Genesee				5 45	Estimated.
Greene				10 25	1 station.
Hamilton				10 15	Mean of 3 stations.
	Piseco Lake	1883	11 00	11 45	Adirondack Survey.
	Morehouseville	1883	8 25	9 10	Do.
Herkimer				9 35	Mean of 12 stations.
	Little Falls	1880	7 20	8 15	N. Y. State Survey.
Jefferson				9 10	Mean of 11 stations.
	Mannsville	1884	6 50	7 35	C. & G. S.
	Pierpont Manor	1874	6 12	7 35	Do.
	Sackett Harbor	1874	9 45	11 10	U. S. Lake Survey.
	Leraysville	1826	5 45	10 15	Adirondack Survey.
	Plessis	1858	7 35	10 00	C. & G. S.
Kings				9 05	1 station, C. & G. S.
Lewis				9 00	Mean of 2 stations.
	Lowville	1821	4 30	9 15	C. & G. S.
Livingston				7 50	1 station.
Madison				8 20	Mean of 8 stations.
	Fenner	1882	7 15	8 05	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Madison	Hamilton	1837	4 30	8 05	Geol. Survey, N. Y.
	Eaton	1879	7 55	8 55	N. Y. State Survey.
	Cazenovia	1843	3 52	7 05	Geol. Survey, N. Y.
Monroe				6 25	Mean of 2 stations.
	Rochester	1893	6 42	7 00	City surveyor.
	Charlotte	1875	4 30	5 50	U. S. Lake Survey.
Montgomery				10 00	Mean of 3 stations.
	Oak Ridge	1880	9 15	10 10	N. Y. State Survey.
	Canajoharie	1839	6 05	9 30	Geol. Survey, N. Y.
New York				9 45	Mean of 8 stations.
Niagara				5 00	Mean of 9 stations.
	Lockport	1895	4 05	4 20	County surveyor.
	Niagara Falls	1874	3 37	5 00	N. A. S.
	Suspension Bridge.	1875	2 24	3 45	U. S. Lake Survey.
	Youngstown	1864	3 00	5 05	Do.
	Fort Niagara	1864	3 00	5 05	Do.
	East Porter	1875	3 15	4 35	Do.
Oneida				9 35	Mean of 9 stations.
	Clinton	1874	8 05	9 30	C. & G. S.
	Prospect	1882	10 50	11 40	Do.
	Utica	1835	3 53	7 40	Silliman's Journal.
	Rome	1879	7 52	8 50	N. Y. State Survey.
	Vienna	1879	8 24	9 25	Do.
Onondaga				8 00	Mean of 9 stations.
	Kirkville	1879	7 03	8 05	N. Y. State Survey.
Ontario	Geneva	1833	3 50	7 50	Geol. Survey, N. Y.
Orange				8 45	Mean of 5 stations.
	Port Jervis	1873	7 05	8 35	C. & G. S.
	Liberty Corner	1874	6 45	8 10	Geol. Survey, N. J.
	Unionville	1874	6 03	7 30	Do.
	Monroe	1859	6 38	9 00	C. & G. S.
	West Point	1835	6 30	10 15	Geol. Survey, N. Y.
Orleans				5 50	Mean of 2 stations.
	Oak Orchard	1875	3 45	5 05	U. S. Lake Survey.
Oswego				9 10	Mean of 2 stations.
	Port Ontario	1874	8 10	9 35	U. S. Lake Survey.
	Sandy Creek	1874	7 50	9 15	Do.
Otsego				9 05	Mean of 2 stations.
	Otsego	1882	8 45	9 35	C. & G. S.
	Cherry Valley	1839	5 13	8 40	Geol. Survey, N. Y.
Putnam	Coldspring	1855	5 35	8 10	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900	Remarks.
			° ′	° ′	
Queens				9 00	Mean of 5 stations.
	Far Rockaway	1875	7 12	8 30	C. & G. S.
	Oyster Bay	1844	6 50	10 00	Do.
	Jamaica	1835	4 00	7 45	Silliman's Journal.
Rensselaer				10 45	Mean of 3 stations.
	Troy	1896	10 57	11 05	W. & L. E. Gurley.
	Greenbush	1855	7 55	10 30	C. & G. S.
Richmond	Cole	1846	5 36	8 40	Do.
Rockland				9 00	Estimated.
St. Lawrence				10 50	Mean of 11 stations.
	Ogdensburg	1838	6 10	9 40	Regent report.
	Colton	1883	9 35	10 20	Adirondack Survey.
Saratoga	Schuyler	1879	8 56	9 55	N. Y. State Survey.
Schenectady				10 45	Mean of 4 stations.
	Schenectady	1859	8 00	10 25	C. & G. S.
Schoharie				10 10	Mean of 4 stations.
Schuyler				7 30	Estimated.
Seneca				7 45	Do.
Steuben				7 20	Mean of 3 stations.
	Bath	1879	5 15	6 15	C. & G. S.
Suffolk				9 50	Mean of 14 stations.
	Fire Island	1860	7 45	10 05	C. & G. S.
	Babylon	1875	7 35	8 55	Do.
	Patchogue	1875	8 00	9 20	Do.
	West Hampton	1875	8 40	10 00	Do.
	Ruland	1865	7 30	9 35	Do.
	East Hampton	1875	9 05	10 25	Do.
	Sag Harbor	1860	8 30	10 50	Do.
	Montauk Point	1875	9 45	11 05	Do.
	Greenpoint	1845	7 15	10 25	Do.
Sullivan				8 45	Estimated.
Tioga				7 20	Mean of 19 stations.
	Owego	1895	7 15	7 30	County surveyor.
	Waverly	1877	5 30	6 40	C. & G. S.
Tompkins				7 00	Mean of 2 stations.
	Ithaca	1895	6 58	7 10	City engineer.
Ulster				10 00	Mean of 2 stations.
	Kingston	1893	9 40	10 00	City engineer.
Warren				11 35	Mean of 12 stations.
	North Creek	1883	11 35	12 20	Adirondack Survey.
	Stony Creek	1883	11 10	11 55	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Warren	Starbuckville	1883	10 32	11 20	Adirondack Survey.
	Johnsburg	1883	10 40	11 25	Do.
	Horicon	1883	10 30	11 15	Do.
	Warrensburg	1883	11 00	11 45	Do.
	Thurman	1883	11 23	12 10	Do.
Washington				11 15	Estimated.
Wayne				7 45	Mean of 5 stations.
	Clyde	1883	7 05	7 50	C. & G. S.
Westchester				9 15	Mean of 7 stations.
	New Rochelle	1844	5 30	8 45	C. & G. S.
	Port Chester	1844	6 00	9 15	Do.
Wyoming	Warsaw	1895	5 15	5 30	County surveyor.
Yates				8 25	1 station.

NORTH CAROLINA.

Declination data in North Carolina are extremely scanty, only 24 counties out of 95 being represented. These observations are derived from the returns of county surveyors, from the United States Coast and Geodetic Survey, and the National Academy of Sciences. Most of them are of recent date, the earliest having been taken in 1847, while the majority bear date later than 1880. These observations have been reduced to 1900 by applying corrections derived from series of observations in this State, South Carolina, and Georgia, as set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 35	1840	3 15
1880	1 05	1830	3 30
1870	1 50	1820	3 45
1860	2 20	1810	4 05
1850	2 45		

The declination is west, except in a few counties in the west end of the State, where it is east. These are distinguished by the letter E. The above corrections are to be added to west declinations and subtracted from east declinations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Alamance		1895	2 00 W.	2 15 W.	County surveyor.
Alexander	Ellendale	1896	0 45 E.	0 35 E.	Do.
Alleghany				0.45 W.	Estimated.
Anson				1.00 W.	Do.
Ashe				0 30 W.	Do.
Beaufort				3 15 W.	Do.
Bertie	Stevenson Point.	1847	1 40 W.	4 35 W.	C. & G. S.
Bladen		1891	0 45 W.	1 15 W.	County surveyor.
Brunswick	Smithville	1887	1 08 W.	1 55 W.	C. & G. S.
Buncombe	Asheville	1873	2 00 E.	0 20 E.	N. A. S.
Burke	Morgantown	1873	1 18 E.	0 15 W.	Do.
Cabarrus				0 50 W.	Estimated.
Caldwell				0 30 W.	Do.
Camden				3 50 W.	Do.
Carteret	Beaufort	1880	1 45 W.	2 50 W.	C. & G. S.
	Portsmouth Isl'd.	1871	2 22 W.	4 10 W.	Do.
Caswell		1887	0.30 E.	0 15 W.	County surveyor.
Catawba				0 45 W.	Estimated.
Chatham				2 00 W.	Do.
Cherokee				0 30 E.	Do.
Chowan				3 30 W.	Do.
Clay				0 15 E.	Do.
Cleveland				0 45 W.	Do.
Columbus				1 45 W.	Do.
Craven	Newbern	1887	1 55 W.	2 40 W.	C. & G. S.
Cumberland				2 00 W.	Estimated.
Currituck				4 00 W.	Mean of 4 stations.
	Coinjock	1874	2 45 W.	4 15 W.	County surveyor.
Dare				3 50 W.	Mean of 2 results. C. & G. S.
Davidson				1 15 W.	Estimated.
Davie				1 00 W.	Do.
Duplin				2 30 W.	Do.
Durham				2 30 W.	Do.
Edgecombe				3 10 W.	Do.
Forsyth				1 15 W.	Do.
Franklin				2 45 W.	Do.
Gaston				0 45 W.	Do.
Gates				3 30 W.	Do.
Graham				0 00	Do.
Granville				2 30 W.	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Greene				2 45 W.	Estimated.
Guilford	Greensboro	1873	0 43 E.	0 55 W.	N. A. S.
Halifax	Weldon	1887	2 30 W.	3 15 W.	C. & G. S.
Harnett				2 15 W.	Estimated.
Haywood				0 10 W.	Do.
Henderson				0 15 W.	Do.
Hertford	Riddicksville	1887	2 30 W.	3 15 W.	C. & G. S.
Hyde				3 30 W.	Estimated.
Iredell				0 45 W.	Do.
Jackson				0 10 W.	Do.
Johnston				2 30 W.	Do.
Jones				2 40 W.	Do.
Lenoir				2 40 W.	Do.
Lincoln	Lincolnton	1896	0 42 W	0 55 W.	County surveyor.
McDowell				0 30 W.	Estimated.
Macon				0 00	Do.
Madison				0 15 W.	Do.
Martin				3 15 W.	Do.
Mecklenburg	Charlotte	1873	1 01 E	0 35 W.	C. & G. S.
Mitchell				0 15 W.	Estimated.
Montgomery				1 15 W.	Do.
Moore				1 45 W.	Do.
Nash				3 00 W.	Do.
New Hanover	Wilmington	1854	1 13 E	1 25 W.	C. & G. S.
Northampton				3 15 W.	Estimated.
Onslow				2 30 W.	Do.
Orange				2 15 W.	Do.
Pamlico				3 00 W.	Do.
Pasquotank				3 45 W.	Do.
Pender				2 15 W.	Do.
Perquimans				3 40 W.	Do.
Person		1895	1 50 W	2 05 W.	County surveyor.
Pitt				3 00 W.	Estimated.
Polk	Columbus	1896	2 05 E.	1 50 E.	County surveyor.
Randolph				1 30 W.	Estimated.
Richmond				1 30 W.	Do.
Robeson				1 30 W.	Do.
Rockingham				1 45 W.	Do
Rowan	Salisbury	1873	0 52 E.	0 45 W.	N. A. S.
Rutherford				0 30 W.	Estimated.
Sampson				2 15 W.	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Stanly				1 00 W.	Estimated.
Stokes				1 15 W.	Do.
Surry				1 00 W.	Do.
Swain				0 00	Do.
Transylvania				0 10 W.	Do.
Tyrrell				3 30 W.	Do.
Union				0 50 W.	Do.
Vance				2 45 W.	Do.
Wake	Raleigh	1887	1 18 W.	2 00 W.	C. & G. S.
	Rolesville	1895	1 30 W.	1 45 W.	County surveyor.
Warren				3 00 W.	Estimated.
Washington				3 30 W.	Do.
Watauga				0 30 W.	Do.
Wayne	Goldsboro	1875	0 15 W.	1 40 W.	N. A. S.
Wilkes				0 40 W.	Estimated.
Wilson				2 50 W.	Do.
Yadkin				0 50 W.	Do.
Yancey				0 10 W.	Do.

NORTH DAKOTA.

The data for North Dakota are derived almost entirely from the surveys of the General Land Office. Some have been obtained from the survey of the northern boundary of the United States and from county surveyors. The Land Office surveys are all of recent date, all of them being subsequent to 1870, and are of excellent quality.

The line of no secular change crossed North Dakota between the years 1845 and 1855; consequently these observations are complicated little, if at all, with the change in secular variation. They have been reduced to the epoch 1900, in accordance with the following table, derived from series of observations in Nebraska and Minnesota, since such observations are almost entirely wanting in this State:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1870	1 50
1880	1 20	1860	2 05

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Allred	Fort Berthold	1860	19 00	16 55	C. & G. S.
Barnes		1875	13 37	12 00	Mean of 42 stations.
Benson		1886	14 19	13 25	Mean of 36 stations.
Billings		1885	16 55	15 55	Mean of 3 stations.
Boreman				13 50	Estimated.
Bottineau		1887	16 05	15 15	Mean of 13 stations.
Bowman				15 45	Estimated.
Buford				17 00	N. Bound'y Survey.
Burleigh		1881	15 11	13 55	Mean of 47 stations.
	Bismarck	1895	14 14	13 55	County surveyor.
Cass		1874	13 30	11 55	Mean of 45 stations.
Cavalier		1885	13 40	12 40	Mean of 48 stations.
Church		1885	15 28	14 30	Mean of 4 stations.
Dickey		1883	13 27	12 20	Mean of 32 stations.
Dunn		1884	16 45	15 40	Mean of 2 stations.
Eddy		1882	14 17	13 05	Mean of 18 stations.
Emmons		1884	15 16	14 10	Mean of 45 stations.
Flannery				16 30	N. Bound'y Survey.
Foster		1883	14 16	13 10	Mean of 18 stations.
Garfield		1888	15 35	14 50	1 station.
Grand Forks		1877	13 54	12 20	Mean of 38 stations.
Griggs		1881	13 30	12 15	Mean of 20 stations.
Hettinger		1891	16 08	15 30	Mean of 13 stations.
Kidder		1878	14 57	13 30	Mean of 40 stations.
Lamoure		1881	13 41	12 25	Mean of 32 stations.
Logan		1883	14 32	13 25	Mean of 28 stations.
McHenry		1886	15 10	14 15	Mean of 29 stations.
McIntosh		1884	14 10	13 05	Mean of 28 stations.
McKenzie				16 20	Estimated.
McLean		1883	16 15	15 10	Mean of 21 stations.
Mercer		1885	15 50	14 50	Mean of 13 stations.
Morton		1884	16 01	14 55	Mean of 52 stations.
Mountraille				16 15	N. Bound'y Survey.
Nelson		1882	13 33	12 20	Mean of 28 stations.
Oliver		1882	15 56	14 45	Mean of 21 stations.
Pembina		1871	14 00	12 15	Mean of 30 stations.
	Pembina	1880	12 36	11 15	C. & G. S.
Pierce		1895	14 03	14 15	Mean of 28 stations.
Ramsey		1885	13 37	12 35	Mean of 33 stations.
	Fort Totten	1880	14 30	13 10	County surveyor.
Ransom		1878	13 19	12 00	Mean of 28 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Ransom	Lisbon	1892	11 30	11 00	County surveyor.
Renville		1893	16 16	15 50	
Richland		1873	13 21	11 35	Mean of 37 stations.
Rolette		1884	14 35	13 30	Mean of 22 stations.
Sargent		1882	12 47	11 35	Mean of 24 stations.
Sheridan		1886	15 32	14 35	Mean of 6 stations.
Stark		1883	16 53	15 45	Mean of 26 stations.
	Dickinson	1895	16 35	16 15	County surveyor.
Steele		1878	13 25	12 00	Mean of 20 stations.
Stevens		1886	15 49	14 55	Mean of 5 stations.
Stutsman		1875	14 38	13 00	Mean of 63 stations.
	Jamestown	1880	13 30	12 10	C. & G. S.
Towner		1885	14 15	13 15	Mean of 31 stations.
Traill		1874	13 34	11 50	Mean of 20 stations.
Wallace				16 15	Estimated.
Walsh		1881	13 35	12 20	Mean of 32 stations.
Ward		1887	16 06	15 15	Mean of 22 stations.
Wells		1885	14 32	13 30	Mean of 31 stations.
Williams		1887	16 04	15 10	Mean of 15 stations.

OHIO.

The declination results for Ohio are derived in the main from the subdivision surveys of the General Land Office, together with a few by the United States Lake Survey, United States Coast and Geodetic Survey, and a number by county surveyors. The Land Office surveys date from the latter part of the last century down to about 1840, and as the line of no secular variation apparently crossed Ohio between the years 1810 and 1820, the reduction of these observations to 1900 is complicated with the change in secular variation. The reductions on account of secular variation, as deduced from the observations made within the State, are set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 45	1840	3 20
1880	1 30	1830	4 10
1870	2 05	1820	4 35
1860	2 30	1810	4 30
1850	2 55	1800	4 40

The line of zero declination crosses this State from north to south. East of this line the declinations are west and are designated by the letter W. West of this line they are east and are designated by the letter E. The preceding reductions on account of secular variation are to be added to west declinations and subtracted from east declinations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adams				0 00	Estimated.
Allen		1832	3 55 E.	0 05 W.	Mean of 5 stations.
Ashland		1807	3 34 E.	1 00 W.	Mean of 8 stations.
Ashtabula	Kingsville	1876	1 15 W.	3 00 W.	U. S. Lake Survey.
	Jefferson	1856	2 45 W.	5 30 W.	County surveyor.
	Conneaut	1865	0 50 E.	1 25 W.	U. S. Lake Survey.
Athens	Athens	1880	0 40 E.	0 50 W.	C. & G. S.
Auglaize		1828	4 17 E.	0 00	Mean of 8 stations.
	Wapakoneta	1883	1 14 E.	0 10 W.	County surveyor.
Belmont	St. Clairsville	1838	2 30 E.	1 00 W.	Silliman's Journal.
Brown				0 45 E.	Estimated.
Butler	Oxford	1845	4 50 E.	1 40 E.	C. & G. S.
Carroll	Carrollton	1895	2 15 W.	2 30 W.	County surveyor.
Champaign				0 00	Estimated.
Clark	Springfield	1835	4 30 E.	0 45 E.	Whittlesey.
Clermont				1 00 E.	Estimated.
Clinton	Wilmington	1895	1 34 E.	1 20 E.	County surveyor.
Columbiana	Lisbon	1895	2 30 W.	2 45 W.	Do.
Coshocton	Coshocton	1838	1 30 E.	2 00 W.	Silliman's Journal.
Crawford		1822	3 29 E.	1 00 W.	Mean of 11 stations.
Cuyahoga	Cleveland	1888	2 04 W.	2 55 W.	C. & G. S.
	Dover	1838	1 50 E.	2 40 W.	Silliman's Journal.
Darke		1801	5 13 E.	0 35 E.	Mean of 16 stations.
	Greenville	1895	2 09 E.	1 55 E.	County surveyor.
	New Madison	1838	4 50 E.	1 20 E.	Silliman's Journal.
Defiance		1822	4 30 E.	0 00	Mean of 9 stations.
Delaware				0 45 W.	Estimated.
Erie				0 34 W.	Mean of 8 stations.
	Sandusky	1877	0 37 E.	1 00 W.	U. S. Lake Survey.
	Kelley Island	1877	0 42 E.	1 00 W.	Do.
Fairfield				1 15 W.	Estimated.
Fayette	Washington	1838	3 06 E.	0 25 W.	Silliman's Journal.
Franklin	Columbus	1871	1 20 E.	0 40 W.	C. & G. S.
Fulton		1823	1 20 E.	0 00	Mean of 13 stations.
Gallia	Gallipolis	1838	2 35 E.	0 55 W.	Silliman's Journal.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Geauga	Chardon	1838	0 15 E.	3 15 W.	Silliman's Journal.
Greene				0 15 E.	Estimated.
Guernsey				2 00 W.	Do.
Hamilton	Hamilton	1895	0 44 E.	0 30 E.	County surveyor.
	Cincinnati	1888	1 58 E.	1 05 E.	C. & G. S.
Hancock		1821	4 30 E.	0 00	Mean of 17 stations.
	Forest	1874	2 18 E.	0 30 E.	C. & G. S.
	Kenton	1838	5 17 E.	1 45 E.	Silliman's Journal.
Hardin		1820	5 03 E.	0 30 E.	Mean of 10 stations.
Harrison				2 30 W.	Estimated.
Henry		1822	4 17 E.	0 10 W.	Mean of 9 stations.
Highland				0 00	Estimated.
Hocking				1 15 W.	Do.
Holmes		1807	2 52 E.	1 40 W.	Mean of 3 stations.
Huron				1 30 W.	Estimated.
Jackson	Jackson	1895	1 16 W.	1 30 W.	Mean of 11 results.
Jefferson	Steubenville	1894	1 12 W.	1 30 W.	County surveyor.
Knox	Mount Vernon	1896	0 15 W.	0 30 W.	Do.
Lake	Willoughby	1876	1 51 W.	3 40 W.	U. S. Lake Survey.
	Fairport	1876	2 00 W.	3 50 W.	Do.
	Madison	1876	2 00 W.	3 50 W.	Do.
Lawrence	Southpoint	1864	1 53 E.	0 25 W.	C. & G. S.
	Ironton	1896	0 40 E.	0 25 E.	County surveyor.
Licking				1 15 W.	Estimated.
Logan		1832	3 50 E.	0 10 W.	1 station.
Lorain		1876	0 36 W.	2 20 W.	Do.
Lucas	Toledo	1895	1 08 W.	1 25 W.	County surveyor.
Madison				0 15 W.	Estimated.
Mahoning				2 30 W.	Do.
Marion		1830	4 17 E.	0 05 E.	Mean of 11 stations.
	Marion	1838	3 17 E.	0 15 W.	Silliman's Journal.
Medina				2 00 W.	Estimated.
Meigs				1 30 W.	Do.
Mercer		1810	5 32 E.	1 00 E.	Mean of 4 stations.
Miami		1799	5 10 E.	0 30 E.	Mean of 5 stations.
Monroe				2 30 W.	Estimated.
Montgomery		1800	5 10 E.	0 30 E.	Mean of 10 stations.
	Carrollton	1845	4 45 E.	1 35 E.	C. & G. S.
Morgan				1 45 W.	Estimated.
Morrow		1811	3 17 E.	1 10 W.	Mean of 8 stations.
Muskingum	Zanesville	1838	2 30 E.	1 00 W.	Silliman's Journal.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Noble	Ridge	1895	1 15 W.	1 35 W.	County surveyor.
	Batesville	1838	1 22 E.	2 10 W.	Silliman's Journal.
Ottawa		1821	3 50 E.	0 45 W.	Mean of 19 stations.
	Port Clinton	1877	0 47 E.	0 55 W.	U. S. Lake Survey.
	Catawba Island	1877	0 40 E.	1 00 W.	Do.
	Locust Point	1877	0 40 E.	1 00 W.	Do.
Paulding		1822	4 48 E.	0 20 E.	Mean of 10 stations.
Perry				1 30 W.	Estimated.
Pickaway				0 30 W.	Do.
Pike	Waverly	1895	0 00	0 20 W.	County surveyor.
Portage	Streetsboro	1821	2 05 E.	2 30 W.	Whittlesey.
Preble		1801	5 04 E.	0 25 E.	Mean of 8 stations.
Putnam		1825	4 20 E.	0 00	Mean of 7 stations.
	Ottawa	1895	0 00	0 20 W.	County surveyor.
	Kalida	1838	3 00 E.	0 30 W.	Silliman's Journal.
Richland	Mansfield	1894	1 27 W.	1 45 W.	County surveyor.
Ross	Chillicothe	1895	0 20 W.	0 40 W.	Do.
Sandusky		1821	3 00 E.	1 35 W.	Mean of 19 stations.
Scioto	Lyra	1895	0 44 W.	1 00 W.	County surveyor.
	Portsmouth	1874	0 20 E.	1 30 W.	Do.
Seneca	Tiffin	1895	0 05 E.	0 15 W.	Do.
	Flatrock	1838	3 15 E.	0 15 W.	Silliman's Journal.
Shelby		1807	4 57 E.	0 25 E.	Mean of 7 stations.
Stark				2 15 W.	Estimated.
Summit	Hudson	1840	0 52 E.	2 30 W.	C. & G. S.
	Akron	1896	1 41 W.	2 00 W.	County surveyor.
Trumbull	Brookfield	1837	0 40 E.	2 50 W.	Silliman's Journal.
	Braceville	1838	0 50 E.	2 40 W.	Do.
Tuscarawas	Tuscarawas	1874	0 20 W.	2 10 W.	N. A. S.
Union	Marysville	1895	1 00 E.	0 40 E.	County surveyor.
Van Wert		1820	4 55 E.	0 20 E.	Mean of 5 stations.
Vinton				1 15 W.	Estimated.
Warren	Springboro	1838	4 04 E.	0 35 E.	Silliman's Journal.
	Lebanon	1891	1 37 E.	1 00 E.	Mean of 9 results.
Washington	Marietta	1895	2 30 W.	2 50 W.	County surveyor.
Wayne	Wooster	1840	1 47 E.	1 30 W.	Silliman's Journal.
Williams		1822	4 36 E.	0 05 E.	Mean of 11 stations.
		1895	0 32 E.	0 15 E.	County surveyor.
Wood	Portage	1838	1 15 E.	2 15 W.	Silliman's Journal.
Wyandot		1824	4 21 E.	0 00	Mean of 6 stations.

OKLAHOMA.

The observations in Oklahoma are derived almost entirely from the subdivisional surveys of the General Land Office. These have been made in recent years, ranging from 1872 to 1891, and are apparently of excellent quality. Data for the correction for secular variation are very scanty, and the following corrections have been assumed on the basis of the corrections in adjacent States:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1870	1 30
1880	1 00		

The declination is east, and these reductions are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Beaver	Western	1891	11 52	11 25	Mean of 12 stations.
	Middle	1891	11 50	11 20	Mean of 54 stations.
	Eastern	1890	11 20	10 50	Mean of 60 stations.
Blaine		1874	10 50	9 35	Mean of 9 stations.
Canadian		1872	10 45	9 20	Mean of 10 stations.
Cleveland		1872	11 10	9 45	Mean of 9 stations.
"D"		1874	11 16	10 00	Mean of 10 stations.
Day		1874	11 27	10 10	Mean of 13 stations.
"G"		1874	10 52	9 35	Mean of 7 stations.
Garfield		1872	10 56	9 30	Mean of 12 stations.
Grant		1872	11 23	10 00	Mean of 13 stations.
Greer		1874	11 18	10 00	Mean of 33 stations.
"I"		1873	10 32	9 10	Mean of 13 stations.
"K"		1872	10 49	9 25	Mean of 9 stations.
Kingfisher		1872	10 47	9 25	Mean of 10 stations.
Kiowa, Comanche, and Apache Reservation.	Northeastern	1874	10 45	9 25	Do.
	Southeastern	1874	11 00	9 45	Mean of 24 stations.
	Northwestern	1874	10 58	9 40	Mean of 12 stations.
	Southwestern	1875	11 14	10 00	Mean of 23 stations.
Lincoln		1877	11 06	10 00	Mean of 12 stations.
Logan		1871	10 38	9 10	Mean of 8 stations.
Noble		1872	11 10	9 45	Mean of 9 stations.
Oklahoma		1872	10 35	9 10	Mean of 14 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Oklahoma	Oklahoma	1895	9 25	9 10	County surveyor.
Osage Nation		1872	10 20	8 55	Mean of 23 stations.
Pawnee		1872	10 10	8 45	Mean of 6 stations.
Payne		1872	10 30	9 05	Mean of 7 stations.
	Stillwater	1896	9 45	9 30	County surveyor.
Pottawatomie		1873	10 00	8 35	Mean of 9 stations.
Roger Mills		1874	11 40	10 20	Mean of 11 stations.
Washita		1874	11 06	9 45	Mean of 8 stations.
Woods		1873	11 20	10 00	Mean of 25 stations.
Woodward		1873	11 40	10 20	Mean of 30 stations.

OREGON.

Observations in Oregon are mainly from the General Land Office, with a few from county surveyors and from the United States Coast and Geodetic Survey. The observations of the General Land Office are of recent date, ranging from 1865 down to the present time.

While data for the determination of secular change are not abundant, there appears to be but little question that the line of no secular variation crossed the State between the years 1885 and 1900, and the data have been reduced in accordance with that hypothesis by means of the figures given in the following table. The last column was derived from series in this State and Washington, with the interpolation of certain figures. The column applying to the eastern portion of the State was derived from the other column, on the assumption that the zero of secular variation passed this part of the State about 1890:

Year.	Reduction.	
	Eastern part	Western part.
	° ′	° ′
1890	0 00	0 05
1880	0 05	0 20
1870	0 20	0 45
1860	0 45	1 05
1850	1 05	1 15
1840	1 45	2 30

The declination is east, and the above corrections are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Baker				19 30	Estimated.
Benton		1891	20 23	20 30	Mean of 9 stations.
	Corvallis	1895	20 00	20 00	County surveyor.
Clackamas		1892	21 17	21 20	Mean of 4 stations.
Clatsop	Astoria	1881	22 26	23 00	C. & G. S.
Columbia		1893	21 20	21 30	Mean of 3 stations.
	Rainier	1895	21 40	21 50	County surveyor.
	St. Helen	1881	19 08	19 30	C. & G. S.
	Clatskanie	1895	21 45	21 55	County surveyor.
	Vernonia	1895	22 30	22 40	Do.
Coos		1884	19 40	20 00	Mean of 4 stations.
	Coos Bay	1863	18 37	19 30	C. & G. S.
Crook	Northeastern	1859	18 55	19 45	Dixon, 1 station.
	Southeastern	1859	18 40	19 30	Do.
	Northwestern	1859	19 15	20 05	Do.
	Southwestern			19 50	Estimated.
	Prineville	1895	20 00	20 00	County surveyor.
Curry	Ewing Harbor	1859	18 30	19 35	Dixon, 1 station.
Douglas		1890	19 17	19 20	Mean of 6 stations.
	Canyonville	1881	17 50	18 10	C. & G. S.
	Oakland	1888	19 25	19 30	Do.
	Roseburg	1896	20 07	20 10	County surveyor.
Gilliam		1888	21 07	21 10	Mean of 3 stations.
	Blalock	1881	20 21	20 25	C. & G. S.
Grant		1895	20 00	20 00	Average of county, by county surveyor.
Harney	Northeastern	1863	18 17	18 50	Mean of 4 stations.
	Southeastern			18 40	Estimated.
	Northwestern			19 10	Do.
	Harney	1876	18 23	18 30	C. & G. S.
Jackson		1893	19 20	19 25	Mean of 6 stations.
	Jacksonville	1881	17 25	17 30	C. & G. S.
Josephine		1893	19 30	19 30	Mean of 2 stations.
Klamath	Northern	1892	19 18	19 20	Mean of 7 stations.
	Southern	1893	19 15	19 20	Mean of 10 stations.
Lake				19 00	Estimated.
Lane		1891	20 02	20 00	Mean of 8 stations.
	Eugene	1881	20 48	21 05	C. & G. S.
Lincoln		1893	19 53	20 00	Mean of 6 stations.
	Yaquina	1888	20 18	20 25	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Lincoln	Waldport	1893	21 00	21 10	County surveyor.
Linn		1891	20 30	20 35	Mean of 5 stations.
	Albany	1895	20 42	20 40	County surveyor.
Malheur	Northern	1859	18 15	19 00	Mean of 4 stations.
	Middle			18 30	Estimated.
	Southern			18 00	Do
Marion		1890	20 22	20 25	Mean of 3 stations.
	Salem	1881	20 00	20 20	C. & G. S.
Morrow				20 30	Estimated.
Multnomah		1887	22 22	22 30	Mean of 2 stations.
	Portland	1881	21 52	22 10	C. & G. S.
Polk		1892	20 30	20 35	1 station.
Sherman				21 00	Estimated.
Tillamook		1892	20 20	20 25	Mean of 5 stations.
	Tillamook	1895	21 54	21 55	County surveyor.
Umatilla		1866	20 20	20 55	Mean of 3 stations.
	Umatilla	1881	21 32	21 35	C. & G. S.
Union		1859	18 40	19 25	Mean of 2 stations
	Grand Ronde	1859	18 20	19 05	Dixon.
Wallowa		1893	20 00	20 00	1 station.
Wasco		1895	20 00	20 00	Said to be average by county surveyor.
	Dalles	1881	20 03	20 20	C. & G. S.
Washington	Hillsboro	1895	21 30	21 30	County surveyor
Yamhill	McMinnville	1895	20 35	20 35	Do.

PENNSYLVANIA.

In this State the subject of magnetic variation has received much attention. In many of the counties meridian lines have been established, upon which the compasses in use are annually tested. The results of such comparisons, with much other data, have been collected by the Secretary of Internal Affairs of the Commonwealth and published from time to time in the records of that department. The latest of these reports, which includes all the data collected up to that date, is that of the year 1887. To that report I am indebted for most of the information regarding magnetic declination in the State. In addition to this, I have received data of more recent date from several county surveyors, besides a few from the United States Coast and Geodetic Survey, National Academy of Sciences, and United States Lake Survey.

Most of these observations are of quite recent date, there being but few in the first half of the century, and but one as far back as 1840. Nearly all of them, indeed, are later than 1870.

The reductions on account of secular variation to the epoch 1900 are as follows, having been derived from series observed in New York, New Jersey, and Pennsylvania:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 25	1840	3 20
1880	0 55	1830	4 15
1870	1 45	1820	4 50
1860	2 20	1810	5 05
1850	2 55		

The declination is west, and the reductions for secular variation are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adams		1877	3 45	4 55	1 station.
Allegheny				3 35	Mean of 4 stations.
	Allegheny	1885	2 56	3 35	C. & G. S.
Armstrong	Freeport	1887	3 30	4 05	Sec. Int. Affairs.
	Leechburg	1896	3 15	3 30	County surveyor.
Beaver				2 45	Mean of 5 stations.
	Beaver	1874	1 08	2 35	C. & G. S.
Bedford	Bedford	1883	3 34	4 20	Sec. Int. Affairs.
Berks	Hamburg	1884	5 17	6 00	Do.
Blair				5 00	Mean of 9 stations.
	Altoona	1895	5 15	5 30	County surveyor.
	Hollidaysburg	1877	4 00	5 10	Sec. Int. Affairs.
	Tyrone	1878	3 43	4 50	Do.
Bradford				7 40	Mean of 3 stations.
	Towanda	1895	7 35	7 45	County surveyor.
Bucks	Doylestown			7 00	Mean of 13 observations. Sec. Int. Affairs.
Butler	Butler			4 25	Mean of 4 observations.
Cambria				3 30	Mean of 2 stations.
	Johnstown	1875	2 20	3 40	Sec. Int. Affairs.
	Cresson	1895	3 08	3 20	County surveyor.
Cameron				5 20	1 station.
Carbon				7 15	Estimated.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Center	Millheim	1893	5 40	5 55	County surveyor.
Chester	West Chester			7 45	Mean of 5 observations. Sec. Int. Affairs.
Clarion	Clarion	1877	2 20	3 30	Sec. Int. Affairs.
Clearfield				5 05	Mean of 2 stations.
	Curwensville	1841	1 45	5 05	C. & G. S.
	Clearfield	1896	4 52	5 05	County surveyor.
Clinton	Beech Creek	1878	3 02	4 05	Sec. Int. Affairs.
Columbia				7 00	Estimated.
Crawford				3 30	Mean of 5 stations.
Cumberland	Carlisle			5 00	Mean of 4 observations.
Dauphin	Harrisburg			6 00	Mean of 13 observations.
Delaware	Chester	1887	6 55	7 30	Sec. Int. Affairs.
Elk				5 00	Mean of 2 stations.
	Wilcox	1887	4 20	4 55	Sec. Int. Affairs.
	Benezette	1887	4 30	5 05	Do.
Erie				4 10	Mean of 13 stations.
	North Springfield	1875	3 00	4 20	U. S. Lake Survey.
	Northeast	1875	2 54	4 15	Do.
	Erie	1883	3 15	4 00	Sec. Int. Affairs.
	Greenfield	1874	2 00	3 25	N. A. S.
	Avonia	1875	2 00	3 20	U. S. Lake Survey.
Fayette	Uniontown			4 00	Mean of 16 observations.
Forest	Tionesta	1895	3 45	4 00	County surveyor.
Franklin	Chambersburg			4 35	Mean of 28 observations.
	Sylvan	1888	4 00	4 30	C. & G. S.
	Mercersburg	1840	0 55	4 15	Do.
Fulton	McConnelsburg			4 50	Mean of 5 observations.
Greene				3 20	Mean of 8 stations.
	Waynesburg	1876	2 03	3 20	Sec. Int. Affairs.
Huntingdon	Huntingdon			5 10	Mean of 8 observations.
Indiana	Indiana	1887	3 45	4 20	Sec. Int. Affairs.
Jefferson	Brookville			4 00	Mean of 42 observations.
Juniata				5 30	Estimated.
Lackawanna				7 30	1 station.
Lancaster				6 30	Estimated.
Lawrence				3 15	Mean of 6 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Lawrence	Newcastle	1853	0 27	3 10	Sec. Int. Affairs.
Lebanon				6 00	1 station.
Lehigh				7 00	Do.
Luzerne	Wilkesbarre	1881	6 30	7 20	Sec. Int. Affairs.
Lycoming	Williamsport			6 20	Mean of 3 observations.
McKean				5 00	Mean of 2 stations.
Mercer				2 55	Mean of 6 stations.
	Sharpsville	1874	1 00	2 25	N. A. S.
	Mercer	1853	0 55	3 40	Sec. Int. Affairs.
Mifflin	Lewistown			4 40	Mean of 10 observations.
Monroe				8 00	1 station.
Montgomery	Hatboro			7 20	Mean of 22 observations.
	Norristown	1892	6 42	7 00	County surveyor.
Montour				6 30	Estimated.
Northampton	Portland	1887	7 05	7 40	Geol. Survey, N. J.
	Bethlehem	1874	5 20	6 45	C. & G. S.
	Easton	1841	3 33	6 50	Do.
Northumberland	Sunbury	1884	5 10	5 55	Sec. Int. Affairs.
Perry				5 45	Estimated.
Philadelphia	Philadelphia	1895	6 44	6 55	City engineer. Mean of 5 stations.
Pike	Milford	1896	7 55	8 10	County surveyor.
Potter				5 20	Mean of 3 stations.
	Coudersport	1887	4 46	5 20	Sec. Int. Affairs.
Schuylkill	Pottsville	1867	4 40	6 35	Do.
Snyder				6 00	Estimated.
Somerset	Somerset			4 20	Mean of 4 observations.
	Milford	1895	4 05	4 20	County surveyor.
Sullivan				7 15	Estimated.
Susquehanna	Montrose	1895	7 58	8 10	County surveyor.
Tioga				6 45	Mean of 2 stations.
	Niles Valley	1893	6 05	6 25	County surveyor.
Union	Lewisburg			6 00	Mean of 5 stations.
	Bucknell Univ.	1895	5 36	5 50	County surveyor.
Venango				3 30	Estimated.
Warren				4 30	Mean of 5 stations.
	Warren	1896	4 57	5 10	County surveyor.
Washington				3 10	Mean of 26 stations.
	Washington	1886	2 30	3 05	Sec. Int. Affairs.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Wayne				8 15	Mean of 5 stations.
	Honesdale	1895	8 03	8 15	County surveyor.
Westmoreland	Greensburg			3 50	Mean of 3 observations.
Wyoming				7 45	Estimated.
York	York	1895	6 08	6 20	County surveyor.

RHODE ISLAND.

The following observations are derived from the compilation of the Coast and Geodetic Survey, the mean of the county always including the stations which are given severally under the county.

The line of no secular variation crossed Rhode Island prior to the beginning of the present century; consequently none of these observations are complicated with the change in secular variation. They have been reduced to the epoch 1900 by the application of corrections deduced from the series observed in western New England, in accordance with the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 20	1840	3 40
1880	0 45	1830	4 40
1870	1 25	1820	5 20
1860	2 05	1810	5 50
1850	2 55	1800	

The declination is west, and the above reductions for secular variation are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Bristol				12 45	Estimated.
Kent				13 00	Mean of 2 stations.
Newport				12 25	Mean of 4 stations.
	Newport	1832	8 12	12 40	C. & G. S.
Providence				12 45	Mean of 3 stations.
	Providence	1885	11 10	11 45	C. & G. S.
Washington				12 15	Mean of 4 stations.

SOUTH CAROLINA.

Declination data in South Carolina are very scanty, only 11 counties out of 35 being represented. These observations are derived mainly from county surveyors and the United States Coast and Geodetic Survey, with one or two other scattering ones. They bear date from 1843 to 1895, most of them having been taken in recent years.

They have been reduced to 1900 by applying corrections derived from series taken in North and South Carolina and Georgia, which are set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 35	1840	3 15
1880	1 05	1830	3 30
1870	1 50	1820	3 45
1860	2 20	1810	4 05
1850	2 45		

The line of zero declination crosses the southwestern part of the State. East of it the declination is west and is distinguished by the letter W. West of it the declination is east and is distinguished by the letter E. The above corrections are to be added to west declinations and subtracted from east declinations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Abbeville				0 15 E.	Estimated.
Aiken	Aiken	1854	3 02 E.	0 25 E.	C. & G. S.
Anderson				0 00	Estimated.
Barnwell				0 00	Do.
Beaufort	Beaufort	1895	1 00 E.	0 45 E.	County surveyor.
	Grahamville	1870	1 55 E.	0 05 E.	C. & G. S.
	Port Royal	1859	3 04 E.	0 45 E.	Do.
Berkeley	Edisto Island	1850	2 53 E.	0 10 E.	Do.
Charleston	Charleston	1847	2 15 E.	0 45 W.	C. Parker.
Chester	Chester	1894	0 30 W.	0 50 W.	County surveyor.
Chesterfield				1 00 W.	Estimated.
Clarendon				0 30 W.	Do.
Colleton	Sullivan Island	1885	0 15 E.	0 35 W.	C. & G. S.
Darlington				0 45 W.	Estimated.
Edgefield				0 30 E.	Do.
Fairfield				0 20 W.	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Florence	Florence	1875	1 12 E.	0 15 W.	N. A. S.
Georgetown	Alston	1854	2 07 E.	0 30 W.	C. & G. S.
Greenville				0 15 W.	Estimated.
Hampton	Robertsville	1843	3 25 E.	0 20 E.	Agricul. register.
Horry				1 15 W.	Estimated.
Kershaw				0 30 W.	Do.
Lancaster				0 30 W.	Do.
Laurens				0 00	Do.
Lexington				0 00	Do.
Marion				1 15 W.	Do.
Marlboro		1895	2 30 W.	2 45 W.	County surveyor.
Newberry				0 00	Estimated.
Oconee				0 00	Do.
Orangeburg				0 00	Do.
Pickens				0 10 W.	Do.
Richland	Columbia	1875	1 50 E.	0 25 E.	N. A. S.
Spartanburg				0 20 W.	Estimated.
Sumter				0 30 W.	Do.
Union				0 20 W.	Do.
Williamsburg				0 40 W.	Do.
York				0 30 W.	Do.

SOUTH DAKOTA.

Observations in South Dakota consist almost exclusively of data obtained from the General Land Office, with a few returns from county surveyors. The Land Office work is of recent date, running from about 1870 down to the present time, and is of excellent quality. The line of no secular variation crossed South Dakota between the years 1855 and 1865, and consequently none of these observations are complicated with the change in the secular variation. They have been reduced by the application of corrections from the following table, derived from observations in Nebraska and Minnesota, no series of observations being obtainable in this State:

Year	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1870	1 56
1880	1 20	1860	2 05

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Aurora		1873	14 14	12 35	Mean of 5 stations.
Beadle		1877	13 14	11 45	Mean of 19 stations.
Bonhomme		1868	13 23	11 30	Mean of 3 stations.
Boreman				13 45	Estimated.
Brookings		1871	12 34	10 45	Mean of 20 stations.
Brown		1881	14 08	12 50	Mean of 35 stations.
Brule		1881	14 05	12 50	Mean of 12 stations.
	Chamberlain	1896	12 43	12 30	County surveyor.
Buffalo		1872	13 41	12 00	Mean of 10 stations.
Butte		1891	15 44	15 20	Mean of 73 stations.
Campbell		1884	14 35	13 35	Mean of 25 stations.
Charles Mix		1872	13 47	12 00	Mean of 17 stations.
Choteau		1892	15 24	14 55	Mean of 20 stations.
Clark		1876	13 26	11 50	Mean of 11 stations.
Clay		1862	12 44	10 45	Do.
Codington		1874	13 10	11 30	Do.
Custer		1883	15 21	14 15	Mean of 16 stations.
	Custer	1896	15 30	15 15	County surveyor.
Davison		1872	13 31	11 50	Mean of 2 stations.
Day		1879	13 29	12 10	Mean of 21 stations.
Delano		1891	15 08	14 30	Mean of 10 stations.
Deuel		1877	12 34	11 05	Mean of 23 stations.
Dewey				13 45	Estimated.
Douglas		1869	14 33	12 45	Mean of 3 stations.
Edmunds		1883	13 56	12 50	Mean of 32 stations.
Ewing		1893	15 47	15 20	Mean of 4 stations.
Fall River		1887	15 19	14 30	Mean of 35 stations.
Faulk		1883	13 45	12 40	Mean of 28 stations.
Grant		1875	12 25	10 50	Mean of 22 stations.
Gregory		1892	12 55	12 20	Mean of 10 stations.
Hamlin		1874	12 31	10 50	Mean of 8 stations.
Hand		1882	13 28	12 20	Mean of 40 stations.
Hanson		1870	12 56	11 05	Mean of 6 stations.
Harding		1891	15 54	15 15	Mean of 21 stations.
Hughes		1882	14 44	13 30	Mean of 27 stations.
Hutchinson		1866	12 30	10 30	Mean of 9 stations.
Hyde		1881	13 28	12 15	Mean of 22 stations.
Jackson		1890	14 00	13 20	Mean of 14 stations.
Jerauld		1875	13 24	11 50	Mean of 10 stations.
	Wessington	1895	12 45	12 25	County surveyor.
Kingsbury		1874	12 44	11 10	Mean of 15 stations.
Lake		1872	12 18	10 30	Mean of 11 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Lawrence		1881	16 10	14 55	Mean of 5 stations.
	Spearfish	1885	16 00	15 00	County surveyor.
Lincoln		1863	12 50	10 50	Mean of 14 stations.
Lugenbeel		1893	13 55	13 30	Mean of 7 stations.
Lyman		1889	13 18	12 30	Mean of 21 stations.
McCook		1870	12 25	10 35	Mean of 16 stations.
McPherson		1884	14 22	13 20	Mean of 32 stations.
Marshall		1881	12 38	11 25	Mean of 30 stations.
Martin		1893	15 44	15 20	Mean of 19 stations.
Meade		1884	15 38	14 40	Mean of 32 stations.
Meyer		1892	13 06	12 35	Mean of 6 stations.
Miner		1877	12 37	11 10	Mean of 11 stations.
Minnehaha		1865	12 06	10 05	Mean of 23 stations.
	Sioux Falls	1889	9 30	8 50	County surveyor.
Moody		1867	12 37	10 40	Mean of 20 stations.
Nowlin		1890	14 10	13 30	Mean of 32 stations.
Pennington		1883	15 19	14 10	Mean of 25 stations.
	Hill	1895	15 15	14 55	County surveyor.
Potter		1883	13 55	12 45	Mean of 27 stations.
Pratt		1890	13 47	13 10	Mean of 30 stations.
Presho		1886	13 25	12 25	Do.
Pyatt		1890	14 23	13 45	Mean of 6 stations.
Rinehart		1892	15 25	14 55	Mean of 16 stations.
Roberts		1876	12 53	11 20	Mean of 24 stations.
Sanborn		1873	13 43	12 05	Mean of 3 stations.
Schnasse				14 15	Estimated.
Scobey		1890	15 11	14 30	Mean of 28 stations.
Shannon		1889	15 13	14 30	Mean of 5 stations.
Spink		1878	13 41	12 15	Mean of 17 stations.
Stanley		1890	13 12	12 30	Mean of 40 stations.
Sterling		1890	14 39	14 00	Mean of 26 stations.
Sully		1882	14 37	13 25	Mean of 33 stations.
Tripp		1893	13 00	12 25	Mean of 10 stations.
Todd				12 00	Estimated.
Turner		1867	12 31	10 40	Mean of 18 stations.
Union		1864	12 04	10 05	Mean of 8 stations.
Wagner		1892	15 45	15 15	Mean of 9 stations.
Walworth		1883	14 05	13 00	Mean of 27 stations.
Washington		1890	14 44	14 05	Mean of 10 stations.
Washabaugh		1892	14 14	13 45	1 station.
Yankton		1864	12 16	10 15	Mean of 8 stations.
	Yankton	1896	11 26	11 10	County surveyor.
Ziebach		1890	14 51	14 10	Mean of 18 stations.

TENNESSEE.

Observations for declination in this State are scanty, not more than half the counties being represented. They are derived from county surveyors, the United States Coast and Geodetic Survey, the National Academy of Sciences, and the survey of the northern boundary of the State. They are of recent date, those of the boundary survey, made in 1859, being the oldest.

They have been reduced to 1900 by the application of corrections from series of observations in this State and Kentucky, which are set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1860	2 10
1880	1 25	1850	2 20
1870	1 40	1840	2 50

The line of zero declination crosses east Tennessee. East of it the declination is west and is designated by the letter W. West of it the declination is east and is distinguished by the letter E. The above corrections are to be added to west declinations and subtracted from east declinations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Anderson				0 45 E.	Estimated.
Bedford				3 15 E.	Do.
Benton				4 30 E.	Do.
Bledsoe				1 30 E.	Do.
Blount				0 00	Do.
Bradley		1895	2 35 E.	2 26 E.	County surveyor.
	Cleveland	1875	3 30 E.	2 00 E.	N. A. S.
Campbell	Caryville	1881	1 12 E.	0 00 W.	C. & G. S.
Cannon				3 00 E.	Estimated.
Carroll				4 30 E.	Do.
Carter				0 15 W.	Do.
Cheatham				4 00 E.	Do.
Chester	Montezuma	1895	3 45 E.	3 35 E.	County surveyor.
Claiborne		1859	4 10 E.	2 00 E.	Boundary Survey.
Clay				3 00 E.	Estimated.
Cocke	Newport	1895	0 15 E.	0 00	County surveyor.
Coffee	Tullahoma	1881	3 30 E.	2 10 E.	C. & G. S.
Crockett				4 50 E.	Estimated.
Cumberland				1 30 E.	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Davidson	Nashville	1896	4 06 E.	3 50 E.	County surveyor.
	Edgefield	1871	5 02 E.	3 25 E.	N. A. S.
Decatur	Perrysville	1895	4 24 E.	4 05 E.	County surveyor.
Dekalb				3 00 E.	Estimated.
Dickson				4 15 E.	Do.
Dyer				4 50 E.	Do.
Fayette				5 00 E.	Do.
Fentress				1 30 E.	Do.
Franklin				2 30 E.	Do.
Gibson	Rutherford	1881	6 00 E.	4 40 E.	C. & G. S.
Giles	Pulaski	1881	5 00 E.	3 40 E.	Do.
Grainger				0 30 E.	Estimated.
Greene				0 00	Do.
Grundy				2 30 E.	Do.
Hamblen				0 15 E.	Do.
Hamilton	Chattanooga	1881	2 26 E.	1 05 E.	C. & G. S.
Hancock				0 20 E.	Estimated.
Hardeman	Grand Junction	1881	6 00 E.	4 40 E.	C. & G. S.
Hardin				4 00 E.	Estimated.
Hawkins	Rogersville	1873	1 49 E.	0 20 E.	N. A. S.
Haywood		1895	4 55 E.	4 35 E.	County surveyor.
Henderson				4 30 E.	Estimated.
Henry				5 15 E.	Mean of 2 stations. Boundary Survey.
Hickman				4 00 E.	Estimated.
Houston				4 30 E.	Do.
Humphreys	Johnsonville	1865	5 50 E.	3 55 E.	C. & G. S.
Jackson		1859	5 37 E.	3 25 E.	Boundary Survey.
James	Long Savannah	1895	2 00 E.	1 40 E.	County surveyor.
Jefferson				0 15 E.	Estimated.
Johnson				0 15 W.	Do.
Knox		1895	0 45 E.	0 25 E.	County surveyor.
	Knoxville	1875	2 15 E.	0 45 E.	N. A. S
Lake	Reelfoot	1895	3 30 E.	3 10 E.	County surveyor.
Lauderdale				5 00 E.	Estimated.
Lawrence				3 30 E.	Do.
Lewis		1895	3 48 E.	3 30 E.	County surveyor.
Lincoln		1895	3 56 E.	3 40 E.	Do.
London				0 45 E.	Estimated.
McMinn	Athens	1881	1 45 E.	0 25 E.	C. & G. S.
McNairy				4 45 E.	Estimated.
Macon		1859	6 21 E.	4 15 E.	Boundary Survey.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Madison	Jackson	1881	5 50 E.	4 30 E.	C. & G. S.
Marion				2 00 E.	Estimated.
Marshall				3 30 E.	Do.
Maury	Columbia	1881	4 36 E.	3 15 E.	C. & G. S.
Meigs				1 00 E.	Estimated.
Monroe	Madisonville	1895	0 15 E.	0 00	County surveyor.
Montgomery				4 30 E.	Estimated.
Moore				3 00 E.	Do.
Morgan				1 00 E.	Do.
Obion		1859	6 17 E.	4 05 E.	Boundary Survey.
Overton				2 55 E.	Mean of 3 stations.
	Livingston	1892	3 30 E.	3 00 E.	County surveyor.
Perry				4 00 E.	Estimated.
Pickett				2 00 E.	Do.
Polk				0 45 E.	Do.
Putnam				2 30 E.	Do.
Rhea				1 00 E.	Do.
Roane				0 45 E.	Do.
Robertson		1859	7 20 E.	5 10 E.	Boundary Survey.
Rutherford	Murfreesboro	1881	4 54 E.	3 35 E.	C. & G. S.
Scott				1 00 E.	Estimated.
Sequatchie				2 00 E.	Do.
Sevier				0 00	Do.
Shelby	Memphis	1877	6 47 E.	5 15 E.	U. S. Engin'r Corps.
Smith	Pleasant Shade	1896	5 08 E.	4 55 E.	County surveyor.
Stewart		1859	6 48 E.	4 35 E.	Boundary Survey.
	Fort Henry	1865	6 24 E.	4 20 E.	C. & G. S.
Sullivan	Bluff City	1895	0 15 E.	0 00	County surveyor.
	Bristol	1881	0 38 E.	0 40 W.	C. & G. S.
Sumner		1895	4 00 E.	3 40 E.	County surveyor.
Tipton				5 15 E.	Estimated.
Trousdale				3 30 E.	Do.
Unicoi				0 15 W.	Do.
Union				1 30 E.	Do.
Van Buren				2 00 E.	Do.
Warren				2 30 E.	Do.
Washington				0 00	Do.
Wayne	Clifton	1865	5 48 E.	3 55 E.	C. & G. S.
Weakley	Gleason	1895	4 20 E.	4 05 E.	County surveyor.
White				2 00 E.	Estimated.
Williamson				3 45 E.	Do.
Wilson				3 30 E.	Do.

TEXAS.

Out of the 245 counties of this State only 87 are represented by observations for magnetic declination. These are derived almost exclusively from the reports from county surveyors, there being a few from the United States Coast and Geodetic Survey, the Mexican Boundary Survey, and a trifling number from other sources. All of these, with the exception of those from the Mexican Boundary Survey, are of recent date; those from the county surveyors being nearly all of date 1895.

They have been reduced to the epoch 1900 by the application of corrections derived from series of observations within the State, and mainly in the eastern half of the State, which are set forth in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 35	1860	1 15
1880	1 05	1850	1 20
1870	1 10	1840	1 20

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Anderson				7 45	Estimated.
Andrews				11 00	Do.
Angelina				7 30	Do.
Aransas	Rockport	1895	7 47	7 30	County surveyor.
Archer	Archer	1894	8 25	8 05	Do.
Armstrong				11 00	Estimated.
Atascosa	Pleasanton	1893	8 55	8 30	County surveyor.
Austin	Sealy	1895	8 50	8 35	Do.
Bailey				11 15	Estimated.
Bandera		1894	8 55	8 35	County surveyor.
Bastrop				8 30	Estimated.
Baylor	Seymour	1884	9 34	8 40	County surveyor.
Bee	Beeville	1895	8 30	8 15	Do.
Bell				8 45	Estimated.
Bexar	San Antonio	1895	9 45	9 30	County surveyor.
Blanco	Johnson	1896	9 15	9 00	Do.
Borden	Gail	1894	9 00	8 40	Do.
Bosque				8 30	Estimated.
Bowie				7 00	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Brazoria		1853	9 05	7 50	C. & G. S.
Brazos				8 15	Estimated.
Brewster				10 30	Do.
Briscoe				10 45	Do.
Brown				9 15	Do.
Buchel				10 30	Do.
Burleson				8 30	Do.
Burnet	Burnet	1873	9 45	8 35	C. & G. S.
Caldwell				8 30	Estimated.
Calhoun		1880	8 20	7 15	U. S. Engin'r Corps.
Callahan				9 30	Estimated.
Cameron	Mouth of Rio Grande.	1854	9 00	7 45	M. Bound. Survey.
Camp				7 15	Estimated.
Carson	Panhandle	1888	11 13	10 35	County surveyor.
Cass	Douglassville	1896	7 00	6 50	Do.
Castro				11 15	Estimated.
Chambers	Wallisville	1895	7 08	6 50	County surveyor.
Cherokee	Rush	1892	8 00	7 30	Do.
Childress				10 30	Estimated.
Clay	Henrietta	1893	8 45	8 20	County surveyor.
Cochran				11 15	Estimated.
Coke				9 45	Do.
Coleman		1895	8 50	8 35	County surveyor.
Collin	McKinney	1894	9 24	9 05	Do.
Collingsworth				10 30	Estimated.
Colorado		1894	9 23	9 00	County surveyor.
Comal		1895	7 47	7 30	Do.
Comanche				9 00	Estimated.
Concho				9 30	Do.
Cooke				8 30	Do.
Coryell				8 45	Do.
Cottle	Paducah	1895	10 09	9 55	County surveyor.
Crane				10 20	Estimated.
Crockett				10 00	Do.
Crosby				10 30	Do.
Dallam				12 00	Do.
Dallas				8 15	Do.
Dawson				10 45	Do.
Deaf Smith				11 30	Do.
Delta				7 30	Do.
Denton				8 30	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Dewitt	Cuero	1889	8 19	7 40	County surveyor.
Dickens				10 00	Estimated.
Dimmit				8 30	Do.
Donley				10 45	Do.
Duval				8 00	Do.
Eastland	Eastland	1889	9 40	9 00	County surveyor.
Ector	Odessa	1891	10 50	10 20	Do.
Edwards				9 00	Estimated.
Ellis				8 15	Do.
El Paso	El Paso	1895	11 43	11 30	County surveyor.
Encinal				8 15	Estimated.
Erath		1888	9 30	8 50	County surveyor.
Falls				8 30	Estimated.
Fannin				8 00	Do.
Fayette				8 20	Do.
Fisher				10 00	Do.
Floyd				11 00	Do.
Foard				10 00	Do.
Foley				10 30	Do.
Fort Bend				8 00	Do.
Franklin				7 30	Do.
Freestone				8 15	Do.
Frio				8 30	Do.
Gaines				11 00	Do.
Galveston	Galveston	1853	9 05	7 50	C. & G. S.
Garza				10 30	Estimated.
Gillespie	Fredericksburg	1895	8 18	8 00	County surveyor.
Glasscock				10 15	Estimated.
Goliad	Goliad	1895	8 15	8 00	County surveyor.
Gonzales	Gonzales	1895	8 18	8 00	Do.
Gray				10 45	Estimated.
Grayson	Denison	1894	9 46	9 30	County surveyor.
	Sherman	1878	9 20	8 15	C. & G. S.
Gregg	Longview	1872	8 40	7 30	N. A. S.
Grimes				8 15	Estimated.
Guadalupe				8 30	Do.
Hale	Plainview	1896	11 30	11 20	County surveyor.
Hall				10 45	Estimated.
Hamilton				8 45	Do.
Hansford				11 00	Do.
Hardeman				10 15	Do.
Hardin				7 30	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Harris				8 00	Estimated.
Harrison				7 00	Do.
Hartley				11 30	Do.
Haskell				9 30	Do.
Hays				8 30	Do.
Hemphill	Canadian	1889	11 04	10 25	County surveyor.
Henderson				7 45	Estimated.
Hidalgo				7 45	Do.
Hill				8 30	Do.
Hockley				11 15	Do.
Hood	Granbury	1892	8 45	8 15	County surveyor.
Hopkins	Sulphur Springs	1888	8 48	8 10	C. & G. S.
Houston	Houston	1895	7 08	6 50	County surveyor.
Howard				10 30	Estimated.
Hunt				7 45	Do.
Hutchinson				11 00	Do.
Irion				10 00	Do.
Jack	Jacksboro	1890	9 05	8 30	County surveyor.
Jackson				8 00	Estimated.
Jasper	Jasper	1895	7 29	7 10	County surveyor.
Jeff Davis				10 45	Estimated.
Jefferson	Beaumont	1890	7 50	7 15	County surveyor.
Johnson				8 30	Estimated.
Jones				9 45	Do.
Karnes				8 15	Do.
Kaufman				8 00	Do.
Kendall				8 45	Do.
Kent				10 00	Do.
Kerr				8 50	Do.
Kimble				9 00	Do.
King				9 45	Do.
Kinney	Spofford	1890	9 13	8 40	County surveyor.
Knox				9 30	Estimated.
Lamar				7 30	Do.
Lamb				11 15	Do.
Lampasas				9 00	Do.
Lasalle				8 30	Do.
Lavaca	Hallettsville	1894	8 45	8 25	County surveyor.
Lee				8 20	Estimated.
Leon				8 15	Do.
Liberty				7 45	Do.
Limestone	Groesbeck	1895	8 55	8 40	County surveyor.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Lipscomb				10 40	Estimated.
Live Oak				8 15	Do.
Llano				9 00	Do.
Loving				11 00	Do.
Lubbock				11 00	Do.
Lynn				11 00	Do.
McCulloch				9 15	Do.
McLennan				8 30	Do.
McMullen				8 15	Do.
Madison				8 15	Do.
Marion				7 00	Do.
Martin				10 30	Do.
Mason	Mason	1894	9 15	8 55	County surveyor.
Matagorda	Matagorda	1877	8 25	7 15	C. & G. S.
Maverick	Eagle Pass	1852	10 00	7 40	Do.
Medina				8 30	Estimated.
Menard				9 15	Do.
Midland	Midland	1887	11 20	10 40	County surveyor.
Milam	Cameron	1893	8 30	8 05	Do.
Mills	Goldthwaite	1895	9 30	9 15	Do.
Mitchell	Colorado	1888	11 00	10 20	C. & G. S.
Montague				8 45	Estimated.
Montgomery	Willis	1838	9 30	8 10	C. & G. S.
Moore				11 15	Estimated.
Morris				7 15	Do.
Motley				10 30	Do.
Nacogdoches	Nacogdoches	1895	8 00	7 45	County surveyor.
Navarro				8 15	Estimated.
Newton	Newton	1895	7 45	7 30	County surveyor.
Nolan				10 00	Estimated.
Nueces				7 45	Do.
Ochiltree				10 45	Do.
Oldham				11 30	Do.
Orange				7 15	Do.
Palo Pinto	Brazos	1823	10 25	9 10	C. & G. S.
Panola		1895	8 00	7 45	County surveyor.
Parker				8 45	Estimated.
Parmer				11 30	Do.
Pecos	Dryden	1896	10 30	10 20	County surveyor.
Polk		1895	8 15	8 00	Do.
Potter				11 15	Estimated.
Presidio				10 45	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Rains				7 45	Estimated.
Randall				11 15	Do.
Red River		1874	9 30	8 20	County surveyor.
Reeves	Pecos	1889	11 22	10 45	Do.
Refugio	Refugio	1887	8 45	8 00	Do.
Roberts				10 45	Estimated.
Robertson	Franklin	1895	8 50	8 35	County surveyor.
Rockwall	Rockwall	1895	7 45	7 30	Do.
Runnels				9 30	Estimated.
Rusk	Henderson	1894	7 50	7 30	County surveyor.
Sabine				7 00	Estimated.
San Augustine				7 15	Do.
San Jacinto				8 00	Do.
San Patricio	San Patricio	1873	9 05	7 45	County surveyor.
San Saba	San Saba	1874	11 00[a]	9 55	C. & G. S.
Schleicher				9 30	Estimated.
Scurry	Snyder	1895	10 17	10 00	County surveyor.
Shackelford				9 30	Estimated.
Shelby	Center	1895	7 20	7 05	County surveyor.
Sherman				11 30	Estimated.
Smith				7 30	Do.
Somervell		1895	9 15	9 00	Conuty surveyor.
Starr	Ringgold Barracks.	1853	9 15	7 55	M. Bound. Survey.
Stephens				9 15	Estimated.
Sterling				10 00	Do.
Stonewall	Rayner	1895	9 45	9 30	County surveyor.
Sutton				9 30	Estimated.
Swisher				11 00	Do.
Tarraut	Fort Worth	1891	8 56	8 25	Conuty surveyor.
Taylor				9 45	Estimated.
Terry				11 00	Do.
Throckmorton				9 30	Do.
Titus				7 15	Do.
Tom Green				10 00	Do.
Travis	Austin	1878	9 00	7 55	C. & G. S.
Trinity				7 45	Estimated.
Tyler				7 30	Do.
Upshur				7 15	Do.
Upton				10 30	Do.
Uvalde				8 45	Do.
Valverde	Del Rio	1895	9 32	9 15	County surveyor.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Van Zandt	Canton	1894	7 22	7 05	County surveyor.
Victoria	Victoria	1895	8 30	8 15	Do.
Walker				8 00	Estimated
Waller	Hempstead	1878	8 36	7 30	C. & G. S.
Ward				10 45	Estimated.
Washington	Brenham	1893	8 28	8 00	County surveyor.
Webb	Old Fort McIntosh.	1852	10 00	8 40	M. Bound. Survey.
Wharton				8 00	Estimated.
Wheeler				10 30	Do.
Wichita				9 30	Do.
Wilbarger	Quanah	1892	10 02	9 35	County surveyor.
Williamson	Georgetown	1893	8 26	8 00	Do.
Wilson				8 30	Estimated.
Winkler				10 45	Do.
Wise				8 45	Do.
Wood	Mineola	1888	8 08	7 30	C. & G. S.
Yoakum				11 15	Estimated.
Young		1894	9 50	9 30	County surveyor.
Zapata				8 00	Estimated.
Zavalla	Batesville	1893	8 50	8 25	County surveyor.

UTAH.

Observations in Utah, are derived from the surveys of the standard lines and township exteriors of the General Land Office, together with a few stations by the United States Coast and Geodetic Survey, the Wheeler Survey, and returns from county surveyors. The Land Office observations in this State, as is the case with all recent observations, are of excellent quality.

The line of no secular variation crossed Utah between the years 1870 and 1880, and the observations have been reduced accordingly, following the subjoined table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	—0 25	1870	0 40
1880	0 40	1860	0 25

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Beaver	Eastern	1882	15 50	15 15	Mean of 10 stations.
	Western	1871	16 34	15 45	Mean of 4 stations.
	Beaver	1885	15 30	14 55	C. & G. S.
	Tamarac	1885	15 31	14 55	Do.
	Tushar	1885	15 22	14 50	Do.
	Milford	1885	15 13	14 40	Do.
Boxelder	Eastern	1881	17 51	17 10	Mean of 35 stations.
	Western	1888	17 41	17 15	Mean of 25 stations.
	Corinne	1881	17 31	16 50	C. & G. S.
	Kelton	1881	17 45	17 50	Do.
	Boxelder	1884	17 28	16 50	Do.
Cache		1892	17 30	17 10	Mean of 9 stations.
Carbon		1894	16 15	16 00	County surveyor.
Davis		1888	17 02	16 30	Mean of 5 stations.
	Farmington	1891	16 29	16 10	County surveyor.
Emery	Northeastern			15 45	Estimated.
	Southeastern			15 30	Do.
	Northwestern	1891	16 12	15 50	Mean of 12 stations.
	Southwestern	1874	16 16	15 35	Mean of 4 stations.
Garfield	Eastern			14 45	Estimated.
	Western			15 15	Do.
Grand				15 20	Do.
Iron	Eastern	1872	16 20	15 40	Mean of 5 stations.
	Western	1879	15 46	15 05	Mean of 3 stations.
Juab	Eastern	1875	16 45	16 05	Mean of 14 stations.
	Western	1883	17 00	16 30	Mean of 2 stations.
	Nephi	1884	16 27	16 00	C. & G. S.
	Fish Spring	1872	17 05	16 25	Wheeler.
	Eureka	1872	17 10	16 30	Do.
Kane	Eastern			14 30	Estimated.
	Western	1878	15 10	14 30	Mean of 9 stations.
	Paria	1872	14 30	13 50	Wheeler.
Millard	Northeastern	1881	16 20	15 40	Mean of 9 stations.
	Southeastern	1870	16 25	15 45	Mean of 5 stations.
	Northwestern			16 00	Estimated.
	Southwestern	1875	16 30	15 50	Mean of 6 stations.
	Deseret	1884	16 10	15 35	C. & G. S.
	Scipio	1884	16 10	15 35	Do.
	Fillmore	1872	16 15	15 35	Wheeler.
Morgan		1879	16 44	16 00	Mean of 9 stations.
Piute		1871	16 05	15 25	Mean of 2 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Rich		1875	17 22	16 40	Mean of 4 stations.
	Meadowville	1877	18 00	17 20	Wheeler.
Salt Lake		1880	16 30	15 50	Mean of 17 stations.
	Salt Lake	1895	16 30	16 20	County surveyor.
	Fort Douglas	1872	17 00	16 20	Wheeler.
San Juan				14 00	Estimated.
San Pete	Northern	1872	16 30	15 50	Mean of 7 stations.
	Southern	1891	16 25	16 00	Mean of 3 stations.
Sevier		1885	16 30	16 00	Mean of 19 stations.
Summit	Eastern	1893	16 25	16 05	Mean of 2 stations.
	Western	1881	16 57	16 20	Mean of 17 stations.
Tooele	Northeastern	1889	16 25	16 00	Mean of 2 stations.
	Southeastern	1873	16 50	16 10	Mean of 15 stations.
	Northwestern			17 00	Estimated.
	Southwestern	1877	16 58	16 20	Mean of 2 stations.
Uinta	Northern	1893	16 22	16 05	Mean of 7 stations.
	Southern			15 30	Estimated.
Utah	Eastern	1884	16 50	16 15	Mean of 6 stations.
	Western	1889	16 30	16 00	Mean of 24 stations.
	Provo	1883	16 32	16 00	C. & G. S.
	Santaquin	1872	17 26	16 45	Wheeler.
	Fairfield	1872	17 00	16 20	Do.
Wasatch	Eastern			16 00	Estimated.
	Western	1880	16 42	16 00	Mean of 7 stations.
Washington		1873	15 56	15 15	Mean of 6 stations.
	St. George	1871	16 27	15 45	Wheeler.
	Toquerville	1872	16 11	15 30	Do.
Wayne		1882	16 00	15 25	Mean of 8 stations.
Weber		1888	17 10	16 40	Do.
	Ogden	1895	16 30	16 15	County surveyor.

VERMONT.

The data for Vermont are derived from the compilation of the Coast and Geodetic Survey, with the addition of a few returns from county surveyors. The earliest of these bears date 1801, and with this exception none of the observations are of sufficiently early date to be complicated with the change in secular variation, since the zero of that term passed over Vermont prior to the beginning of the present century.

In the reduction of these observations to the epoch 1900 the corrections appearing in the following table, determined from the series observed in western New England, have been applied:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 20	1840	3 40
1880	0 45	1830	4 40
1870	1 25	1820	5 20
1860	2 05	1810	5 50
1850	2 55	1800	6 10

The declination is west, and the correction for secular variation is to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Addison	Middlebury	1896	11 22	11 30	County surveyor.
Bennington				11 30	Estimated.
Caledonia	Ryegate	1801	7 00	13 10	Silliman's Journal.
	St. Johnsbury	1837	9 16	13 15	Do.
Chittenden	Burlington	1873	11 20	12 35	C. & G. S.
	Essex Junction	1849	9 24	12 25	Do.
Essex				14 30	Estimated.
Franklin	Swanton Falls	1850	11 28	14 25	C. & G. S.
Grand Isle	North Hero	1895	13 00	13 10	County surveyor.
Lamoille				13 30	Estimated.
Orange	Wells River	1875	11 55	13 00	N. A. S.
Orleans	Barton	1837	10 50	14 50	Silliman's Journal.
	Derby	1876	13 18	14 20	N. A. S.
Rutland	Rutland	1879	11 09	12 00	C. & G. S.
Washington				13 00	Estimated.
Windham	Newfane	1895	12 00	12 10	County surveyor.
	Brattleboro	1895	11 55	12 05	Do.
	Winhall	1895	12 15	12 25	Do.
	Bellows Falls	1876	11 07	12 10	N. A. S.
Windsor	Woodstock	1896	12 30	12 40	County surveyor.
	White River Junction.	1876	11 05	12 05	N. A. S.
	West Hartford	1860	11 09	13 15	C. & G. S.

VIRGINIA.

Data for magnetic declination in Virginia are very scanty, consisting of a few observations by the United States Coast and Geodetic Survey, National Academy of Sciences, and county surveyors. With very few exceptions, the data are of recent date, at least coming within the last half of the century, and most of it within the last twenty or thirty years. With the exception of two observations from Boyé's map of Virginia, all of these observations are of recent date.

The line of no secular variation is supposed to have crossed the middle of Virginia about the year 1810.

The following is the table of reductions on account of secular variation to the epoch 1900, derived from a series of observations taken in Delaware, Maryland, District of Columbia, Virginia, and West Virginia:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1840	3 30
1880	1 00	1830	4 00
1870	1 55	1820	4 10
1860	2 25	1810	4 20
1850	3 00		

The zero of magnetic declination crosses the southwestern part of the State. East of that line the declination is west and west of that line it is east. Unless otherwise designated it is to be understood that the declination is west. The above reductions on account of secular variation are to be added to west declination and subtracted from east declination.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
Accomac		1894	4 18	4 35	Mean of 4 stations.
Albemarle	Charlottesville	1887	2 00	2 40	C. & G. S.
	Greenwood	1880	2 19	3 20	Do.
Alexandria				4 30	Estimated.
Alleghany	Covington	1890	1 15	1 45	County surveyor.
Amelia				3 15	Estimated.
Amherst	Amherst	1878	2 00	3 10	County surveyor.
Appomattox				2 30	Estimated.
Augusta	Staunton	1895	2 00	2 15	County surveyor.
Bath				2 15	Estimated.
Bedford				2 00	Do.
Bland				1 00	Do.

County.	Town, city, etc.	Year of observation	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Botetourt				1 45	Estimated.
Brunswick		1824	0 52 E.	3 15 W.	Boyé map.
Buchanan				0 30	Estimated.
Buckingham				3 00	Do.
Campbell	Lynchburg	1873	0 34	2 10	N. A. S.
Caroline	Sparta	1893	3 35	3 55	County surveyor.
Carroll				1 00	Estimated.
Charles City				3 45	Do.
Charlotte				2 45	Do.
Chesterfield				3 30	Do.
Clarke				4 00	Do.
Craig	Simmonsville	1894	0 54	1 10	County surveyor.
Culpeper	Culpeper	1873	2 21	3 55	N. A. S.
Cumberland	Courthouse	1895	3 00	3 15	County surveyor.
Dickinson				0 15	Estimated.
Dinwiddie	Petersburg	1871	1 30	3 20	C. & G. S.
Elizabeth City	Old Pt. Comfort.	1856	1 15	3 55	Do.
Essex		1895	4 00	4 15	County surveyor.
Fairfax	Bealeton	1895	4 10	4 25	Do.
	Bull Run	1871	4 22	6 15	C. & G. S.
	Peach Grove	1870	2 55	4 50	Do.
Fauquier				3 45	Estimated.
Floyd		1895	4 30	4 45	County surveyor.
Fluvanna				3 00	Estimated.
Franklin				1 45	Do.
Frederick				4 00	Do.
Giles	Pembroke	1882	2 00 W.	2 55	County surveyor.
Gloucester				4 00	Estimated.
Goochland				3 15	Do.
Grayson	Peach Bottom	1824	3 50	0 15	Boyé map.
Greene				3 00	Estimated.
Greenesville				3 15	Do.
Halifax	Houston	1896	2 03	2 15	County surveyor.
	Meadville	1886	1 30	2 15	C. & G. S.
Hanover				3 30	Estimated.
Henrico	Richmond	1856	0 15 W.	3 00	C. & G. S.
Henry				1 45	Estimated.
Highland				2 30	Do.
Isle of Wight				3 45	Do.
James City	Williamsburg	1887	3 03	3 45	C. & C. S.
King and Queen				4 00	Estimated.
King George	Comorn	1895	4 00	4 15	County surveyor.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
King William	Court-house	1896	3 15	3 30	County surveyor.
Lancaster	Lancaster	1890	4 00	4 30	Do.
Lee	Jonesville	1890	0 30 E.	0 00	Do.
Loudoun	Farmwell	1895	3 00	3 15	Do.
Louisa	Louisa	1895	3 20	3 35	Do.
Lunenburg				3 00	Estimated.
Madison	Court-house	1896	3 15	3 30	County surveyor.
Mathews	Court-house	1895	4 56	5 10	Do.
	Wolf Trap	1871	2 50	4 45	C. & G. S.
Mecklenburg				3 00	Estimated.
Middlesex				4 15	Do.
Montgomery	Christiansburg	1889	0 55	1 30	County surveyor.
Nansemond		1895	2 57	3 10	Do.
	Hines	1887	3 05	3 45	C. & G. S.
Nelson				2 30	Estimated.
New Kent				4 00	Do.
Norfolk	Norfolk			3 30	Mean of 3 results.
	Gosport Navy-Yard.	1865	2 38	4 45	Smithsonian Inst.
Northampton	Cape Charles	1856	1 36	4 20	C. & G. S.
	Scott	1856	1 31	4 15	Do.
Northumberland.				4 30	Estimated.
Nottoway	Burke	1873	2 00	3 35	N. A. S.
Orange	Clark Mountain	1871	1 47	3 35	C. & G. S.
Page	Luray	1895	3 35	3 50	County surveyor.
Patrick				1 30	Estimated.
Pittsylvania	Danville	1873	1 16	2 55	N. A. S.
	Mount Airy	1873	0 55 E.	0 40	Do.
Powhatan	Scottsville	1879	2 30	3 35	C. & G. S.
Prince Edward				3 00	Estimated.
Prince George				3 30	Do.
Princess Anne	Knott Island	1873	2 55	4 30	C. & G. S.
	Cape Henry	1887	3 20	4 00	Do.
Prince William				4 00	Estimated.
Pulaski				1 15	Do.
Rappahannock	Washington	1896	3 52	4 05	County surveyor.
Richmond				4 15	Estimated.
Roanoke				1 30	Do.
Rockbridge	Natural Bridge	1873	0 05	1 40	N. A. S.
Rockingham	Harrisonburg	1895	2 32	2 45	County surveyor.
Russell				1 15	Estimated.
Scott				0 00	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Shenandoah	Strasburg	1884	2 58	3 50	C. & G. S.
Smyth	Marion	1881	0 02 E.	1 00	Do.
Southampton				3 30	Estimated.
Spottsylvania	Court-house	1895	3 30	3 45	County surveyor.
	Fredericksburg	1856	1 02	3 45	C. & G. S.
Stafford	Court-house	1895	3 37	3 50	County surveyor.
Surry				3 45	Estimated.
Sussex				3 30	Do.
Tazewell				1 45	Do.
Warren				3 30	Do.
Warwick				4 00	Do.
Washington	Emory and Henry Coll.	1881	1 00 E.	0 00	C. & G. S.
Westmoreland				4 30	Estimated.
Wise				0 00	Do.
Wythe	Wytheville	1881	0 00	1 00	C. & G. S.
York				4 00	Estimated.

WASHINGTON.

Results in Washington have been derived mainly from the General Land Office, with a few from the United States Coast and Geodetic Survey and from county surveyors. In the county means only Land Office observations are included. These are of recent date, ranging from 1868 to the present time.

Data for the determination of the secular change are mainly from the western part of the State. All indications point to the passage of the line of no variation across the State between the years 1885 and 1900, and the observations have been reduced accordingly, using the table herewith presented.

Year.	Reduction.	
	Eastern part.	Western part.
	° ′	° ′
1890	0 00	+0 05
1880	+0 05	0 20
1870	0 20	0 45
1860	0 45	1 05
1850	1 05	1 45
1840	1 45	2 30

The second column, that applying to the western part of the State, has been derived from series in Oregon and Washington, to which certain values have been added by interpolation. It indicates the passage of the zero of secular variation in 1900. The other column is derived from the latter, assuming that the zero passed in 1890.

The declination is east, and the above corrections are to be added.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adams		1872	21 18	21 30	Mean of 10 stations.
Asotin		1876	21 35	21 40	Mean of 3 stations.
Chehalis		1884	22 08	22 10	Mean of 14 stations.
	Aberdeen	1894	22 30	22 30	County surveyor.
Clallam		1884	22 26	22 40	Mean of 27 stations.
	Neah Bay	1881	22 45	23 05	C. & G. S.
Clarke	Vancouver	1881	20 53	21 00	Do.
Columbia		1861	21 00	22 05	Mean of 4 stations.
Cowlitz		1877	21 35	22 00	Mean of 8 stations.
Douglas		1887	22 16	22 20	Mean of 19 stations.
Franklin		1866	21 10	22 00	Mean of 6 stations.
Garfield		1870	21 26	21 45	Mean of 3 stations.
	Pomeroy	1881	21 34	21 40	C. &. G. S.
Island		1856	21 30	23 00	1 station.
Jefferson		1884	22 07	22 30	Mean of 4 stations.
	Port Townsend	1881	21 27	21 45	C. & G. S.
King		1871	21 57	22 40	Mean of 18 stations.
	Seattle	1888	22 30	22 35	C. & G. S.
Kitsap		1894	22 30	22 40	1 station.
Kittitas		1880	21 40	21 40	Mean of 12 stations.
Klickitat		1874	20 54	21 00	Mean of 8 stations.
Lewis		1876	21 21	21 50	Mean of 12 stations.
Lincoln		1874	21 41	21 50	Mean of 9 stations.
	Sprague	1881	22 55	23 00	C. & G. S.
Mason		1874	21 38	22 10	Mean of 5 stations.
Okanogan		1883	22 32	22 35	Mean of 2 stations.
	Conconully	1890	22 55	22 55	County surveyor.
Pacific		1880	21 42	22 00	Mean of 9 stations.
Pierce		1873	21 15	21 55	Mean of 11 stations.
San Juan				23 00	Estimated.
Skagit		1882	22 19	22 40	Mean of 7 stations.
Skamania		1893	23 15	23 15	Mean of 3 stations.
Snohomish		1880	22 29	22 50	Mean of 13 stations.
Spokane		1876	22 03	22 20	Mean of 7 stations.
	Spokane	1881	21 40	21 45	C. & G. S.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Stevens		1876	23 00	23 35	Mean of 5 stations.
Thurston		1868	21 37	22 25	Mean of 8 stations.
	Olympia	1895	22 20	22 20	County surveyor.
Wakiakum		1895	22 30	22 35	Do.
Wallawalla		1878	20 50	20 55	Mean of 4 stations.
	Wallula	1881	19 56	20 00	C. & G. S.
	Ainsworth	1881	21 25	21 30	Do.
	Wallawalla	1887	21 10	21 10	Do.
Whatcom		1879	22 35	22 55	Mean of 8 stations.
Whitman		1871	20 49	21 35	Mean of 11 stations.
Yakima		1874	21 04	21 40	Mean of 47 stations.

WEST VIRGINIA.

Observations for magnetic declination in this State are extremely scanty, only 20 counties out of 54 being represented by observations. These observations are derived from county surveyors, from the United States Coast and Geodetic Survey, National Academy of Sciences, and in one or two cases from the Boyé map of Virginia. With the exception of those last mentioned the observations are of comparatively recent date, the earliest being taken in 1864.

It is believed that the line of no secular variation crossed West Virginia about 1810, and consequently none of these observations are affected by the change in secular variation, with the exception of those taken from the Boyé map.

The following is the table of reduction to the epoch 1900 on account of secular variation, derived from series observed in Delaware, Maryland, District of Columbia, Virginia, and West Virginia:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 30	1840	3 30
1880	1 00	1830	4 00
1870	1 55	1820	4 10
1860	2 25	1810	4 20
1850	3 00		

The declination in 1900 is west in all cases. In a few cases the observed declination is east, and is so designated. The above reductions are to be added to west declination and subtracted from east declination.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Barbour				3 00	Estimated.
Berkeley	Martinsburg	1873	2 51	4 25	N. A. S.
Boone				1 00	Estimated.
Braxton	Bulltown	1824	2 10 E.	2 00	Boyé map.
Brooke				3 00	Estimated.
Cabell				1 00	Do.
Calhoun		1892	0 45	1 10	County surveyor.
Clay				1 30	Estimated.
Doddridge				2 30	Do.
Fayette				1 30	Do.
Gilmer	Glenville	1896	1 05 W.	1 20	County surveyor.
Grant				3 45	Estimated.
Greenbrier				1 30	Do.
Hampshire				3 45	Do.
Hancock	New Cumberland	1895	2 50	3 05	County surveyor.
Hardy				3 15	Estimated.
Harrison	Clarksburg	1880	1 45	2 45	C. & G. S.
Jackson				1 30	Estimated.
Jefferson				4 00	Do.
Kanawha	Charleston	1881	1 03	2 00	C. & G. S.
Lewis	Edmiston	1885	2 00	2 45	County surveyor.
Lincoln				1 00	Estimated.
Logan				0 45	Do.
McDowell				0 45	Do.
Marion	Fairmont	1889	2 31	3 10	County surveyor.
Marshall	Cameron	1864	0 24 E.	1 50	C. & G. S.
Mason	Point Pleasant	1864	1 35 E.	0 35	Do.
Mercer				1 00	Estimated.
Mineral		1824	1 35 E.	2 30	Boyé map.
Mingo				0 45	Estimated.
Monongalia				3 15	Do.
Monroe	Alderson	1881	0 55	1 55	C. & G. S.
Morgan				4 00	Estimated.
Nicholas				2 00	Do.
Ohio	Wheeling	1881	0 00	1 00	C. & G. S.
Pendleton	Upper Front	1883	1 10	2 00	County surveyor.
Pleasants				2 00	Estimated.
Pocahontas	Edray	1872	0 20	2 05	County surveyor.
Preston				3 30	Estimated.
Putnam				1 15	Do.
Raleigh				1 15	Do.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Randolph				2 30	Estimated.
Ritchie				2 00	Do.
Roane				1 30	Do.
Summers				1 30	Do.
Taylor	Grafton	1864	1 52	4 05	C. & G. S.
	Prunty	1883	2 33	3 25	Do.
Tucker				3 00	Estimated.
Tyler				2 30	Do.
Upshur				2 30	Do.
Wayne				0 30	Do.
Webster				2 10	Do.
Wetzel				2 30	Do.
Wirt		1895	2 45	3 00	County surveyor.
Wood	Parkersburg	1881	0 12	1 10	C. & G. S.
Wyoming				1 00	Estimated.

WISCONSIN.

Observations in Wisconsin are derived in the main from surveys of the General Land Office, and in smaller part from the work of the United States Lake Survey, which data are confined to the northern border of the State, returns from county surveyors, and a few observations from other sources.

The Land Office work was done between the years 1830 and 1845, and the results are given, as in other cases, in the form of means of numerous stations within the county.

These observations have been reduced to 1900 by means of corrections obtained from series of observations of different dates taken within the State. These corrections are given in the following table:

Year.	Reduction.	Year.	Reduction.
	° ′		° ′
1890	0 40	1860	2 30
1880	1 20	1850	2 40
1870	1 55	1840	3 05

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Adams				4 30	Estimated.
Ashland				5 55	Mean of 7 stations, by Lake Survey.
Barron				6 30	Estimated.
Bayfield				6 00	Do.
Brown		1839	6 27	3 20	Mean of 26 stations.
	Fort Howard	1884	4 26	3 25	C. & G. S.
Buffalo				6 30	Estimated.
Burnett				8 00	Do.
Calumet		1837	6 35	3 10	Mean of 11 stations.
	New Holstein	1895	4 40	4 20	County surveyor.
Chippewa		1895	5 47	5 30	Do.
Clark	Neillsville	1891	5 28	4 50	Do.
Columbia		1836	7 40	4 15	Mean of 9 stations.
	Portage	1895	4 45	4 25	County surveyor.
Crawford		1842	8 03	5 00	Mean of 10 stations.
Dane		1833	9 00	5 15	Mean of 5 stations.
	Blue Mound	1840	8 38	5 35	Locke's Report on Min. Land.
	Madison	1888	5 54	5 05	C. & G. S.
Dodge		1835	7 10	3 50	Mean of 21 stations.
Door		1836	6 20	3 00	Mean of 48 stations.
Douglas	Superior	1880	9 45	8 25	C. & G. S.
Dunn				7 00	Estimated.
Eau Claire	Eau Claire	1894	6 25	6 00	County surveyor.
Florence	Florence	1896	4 21	4 00	Do.
Fond du Lac		1835	6 53	3 35	Mean of 20 stations.
Forest				4 00	Estimated.
Grant		1837	8 53	5 40	Mean of 24 stations.
Green		1834	8 27	5 05	Mean of 9 stations.
	Mount Pleasant	1894	4 45	4 25	County surveyor.
	Monroe	1859	8 24	5 55	C. & G. S.
Green Lake		1834	7 50	4 30	Mean of 10 stations.
Iowa		1836	8 25	5 05	Mean of 27 stations.
	Mineral Point	1840	8 40	5 35	C. & G. S.
Iron					Estimated.
Jackson				6 00	Do.
Jefferson		1836	6 50	3 30	Mean of 16 stations.
	Oakland	1885	5 20	4 20	County surveyor.
Juneau	Mauston	1895	5 00	4 40	Do.
	New Lisbon	1884	4 55	3 55	C. & G. S.
Kenosha		1836	6 02	2 40	Mean of 5 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Kenosha	Kenosha	1872	5 00	3 15	C. & G. S.
Kewaunee		1840	6 10	3 05	Mean of 3 stations.
	Kewaunee			3 15	Mean of 2 results.
La Crosse	La Crosse	1877	8 38	7 00	C. & G. S.
Lafayette		1833	8 42	5 15	Mean of 17 stations.
Langlade				4 30	Mean of 2 stations.
Lincoln				4 30	Estimated.
Manitowoc		1835	6 30	3 10	Mean of 10 stations.
	Manitowoc	1870	5 02	3 10	U. S. Lake Survey.
Marathon		1840	7 44	4 40	Mean of 8 stations.
Marinette		1837	6 46	3 30	Mean of 18 stations.
	Peshtigo	1865	4 20	2 10	U. S. Lake Survey.
Marquette				4 15	Estimated.
Milwaukee	Milwaukee	1888	4 22	3 35	C. & G. S.
Monroe		1895	6 32	6 15	County surveyor.
Oconto		1840	6 26	3 20	Mean of 8 stations.
	Oconto	1865	5 21	3 10	U. S. Lake Survey.
Oneida		1895	3 45	3 25	County surveyor.
Outagamie		1839	6 13	3 00	Mean of 21 stations.
	Appleton	1895	3 35	3 15	County surveyor.
Ozaukee		1835	7 00	3 40	1 station.
Pepin	Arkansas	1895	6 00	5 40	County surveyor.
Pierce	Bay City	1869	8 10	6 10	U. S. Lake Survey.
Polk				7 30	Estimated.
Portage		1840	8 06	5 00	Mean of 7 stations.
Price		1886	5 26	4 25	1 station, by county surveyor.
Racine		1836	6 10	2 50	Mean of 5 stations.
	Racine	1872	4 30	2 45	C. & G. S.
Richland		1840	8 36	5 30	Mean of 11 stations.
Rock		1834	8 02	4 40	Mean of 21 stations.
	Janesville	1892	4 57	4 20	County surveyor.
St. Croix				7 30	Estimated.
Sauk		1839	8 00	4 55	Mean of 7 stations.
	Baraboo	1893	4 30	4 00	County surveyor.
Sawyer		1895	6 00	5 40	Do.
Shawano		1841	5 55	2 55	Mean of 3 stations.
Sheboygan		1835	7 02	3 40	Mean of 16 stations.
	Sheboygan City	1894	3 20	3 00	County surveyor.
Taylor				5 00	Estimated.
Trempealeau		1896	6 30	6 15	County surveyor.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Vernon		1894	6 09	5 50	County Surveyor.
Vilas				3 30	Estimated.
Walworth		1835	6 34	3 15	Mean of 16 stations.
Washburn				7 00	Estimated.
Washington		1836	7 28	4 05	Mean of 3 stations.
Waukesha		1836	5 23	2 05	Mean of 2 stations.
Waupaca		1844	6 15	3 20	Mean of 3 stations.
Waushara		1835	6 50	3 30	1 station.
Winnebago		1836	6 40	3 20	Mean of 17 stations.
	Winneconne	1874	7 28	5 50	County surveyor.
Wood		1840	8 13	5 10	Mean of 4 stations.

WYOMING.

Observations consist almost exclusively of results from the surveys of standard lines and exteriors of the General Land Office, together with a few from the Coast and Geodetic Survey and the Wheeler Survey. The Land Office surveys in this State, being of recent date, are of excellent quality. Most of them have been executed subsequent to 1880.

The line of no secular variation crossed Wyoming between the years 1860 and 1870, and the observations have been corrected accordingly by the use of the following table:

Year.	Reduction.	
	Eastern part.	Western part.
	° ′	° ′
1890	0 40	0 30
1880	1 10	0 50
1870	1 25	1 00
1860	1 40	0 50

The column applying to the eastern part of the State was derived from series observed in Colorado, since data for the determination of secular variation are practically wanting in Wyoming. The last column was derived from the first, on the assumption that the zero of secular variation passed through that part of the State about 1870.

The declination is east, and the above corrections are to be subtracted.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Albany	Northern	1878	15 50	14 40	Mean of 12 stations.
	Southern	1880	15 35	14 30	Mean of 6 stations.
	Laramie	1895	14 24	14 10	County surveyor.
	Sherman	1872	15 53	13 35	C. & G. S.
	Rock Creek	1878	15 45	14 35	Do.
	Fort Sanders	1873	15 30	14 10	Wheeler.
Bighorn	Northeastern	1883	19 13	18 30	Mean of 28 stations.
	Southeastern	1884	18 50	18 00	Mean of 44 stations.
	Northwestern	1882	20 07	19 20	Mean of 11 stations.
	Southwestern	1883	19 56	19 15	Mean of 8 stations.
Carbon	Northeastern	1881	16 27	15 40	Mean of 11 stations.
	Southeastern	1884	16 02	15 20	Mean of 14 stations.
	Northwestern	1881	16 30	15 45	Mean of 16 stations.
	Southwestern	1881	15 48	15 00	Do.
	Fort Steele	1878	16 10	15 15	C. & G. S.
Converse	Northeastern	1881	15 04	14 00	Mean of 24 stations.
	Southeastern	1879	15 40	14 40	Mean of 17 stations.
	Northwestern	1881	15 55	14 50	Mean of 28 stations.
	Southwestern	1882	15 43	14 40	Mean of 19 stations.
Crook	Eastern	1882	16 10	15 10	Mean of 26 stations.
	Western	1882	16 55	16 00	Mean of 44 stations.
	Sundance	1889	15 45	15 00	County surveyor.
Fremont	Northeastern	1890	16 50	16 20	Mean of 35 stations.
	Southeastern	1882	16 43	16 00	Mean of 17 stations.
	Northwestern	1892	17 52	17 30	Mean of 22 stations.
	Southwestern	1891	17 07	16 40	Mean of 18 stations.
Johnson	Northeastern	1882	16 10	15 25	Mean of 19 stations.
	Southeastern	1881	16 34	15 50	Do.
	Northwestern	1880	15 50	15 00	Mean of 13 stations.
	Southwestern	1881	17 18	16 25	Mean of 16 stations.
	Fort McKinney	1877	17 00	16 00	U. S. Eng'r Corps.
Laramie	Northeastern	1878	15 30	14 20	Mean of 18 stations.
	Southeastern	1882	15 06	14 00	Mean of 3 stations.
	Northwestern	1878	15 28	14 20	Mean of 13 stations.
	Southwestern	1878	15 20	14 10	Mean of 2 stations.
	Cheyenne	1878	15 20	14 10	C. & G. S.
	Chugsprings	1877	15 26	14 10	U. S. Eng'r Corps.
	Fort Laramie	1877	15 25	14 10	Do.
Natrona	Northeastern	1881	16 38	15 40	Mean of 23 stations.
	Southeastern	1882	16 30	15 30	Mean of 13 stations.
	Northwestern	1883	18 12	17 20	Mean of 17 stations.

County.	Town, city, etc.	Year of observation.	Observed declination.	Declination in 1900.	Remarks.
			° ′	° ′	
Natrona	Southwestern	1883	16 46	16 00	Mean of 18 stations.
Sheridan	Eastern	1882	16 50	16 00	Mean of 25 stations.
	Western	1870	17 00	15 50	Mean of 2 stations.
Sweetwater	Northeastern	1882	16 28	15 40	Mean of 30 stations.
	Southeastern	1881	15 48	15 00	Mean of 9 stations.
	Northwestern	1885	16 45	16 00	Mean of 11 stations.
	Southwestern	1880	15 45	15 00	Do.
	Green River	1878	16 45	15 50	C. & G. S.
	Point of Rocks	1878	16 18	15 25	Do.
	Creston	1878	16 04	15 10	Do.
Uinta	Northern	1882	17 40	17 00	Mean of 17 stations.
	Middle	1887	17 36	17 00	Mean of 41 stations.
	Southern	1880	17 00	16 10	Mean of 14 stations.
	Carter	1878	17 06	16 10	C. & G. S.
	Fort Bridger	1858	16 38	16 00	Simpson.
	Evanston	1892	16 35	16 00	County surveyor.
Weston	Eastern	1881	15 05	14 00	Mean of 23 stations.
	Western	1881	15 55	14 55	Mean of 34 stations.
Yellowstone National Park.		1874	18 58	18 00	Mean of 7 stations, by Hayden.

A GEOLOGICAL RECONNAISSANCE IN NORTHWESTERN OREGON.

BY

JOSEPH SILAS DILLER.

CONTENTS.

ILLUSTRATIONS.

A GEOLOGICAL RECONNAISSANCE IN NORTHWESTERN OREGON.

By J. S. Diller.

INTRODUCTION.

Coal has long been mined at one place in northwestern Oregon, and has been reported from many others. Gold and other minerals have been found in the same region, and on account of their bearing upon the economic interests of the State, the Director of the Geological Survey instructed the writer to make a general reconnaissance of that portion of the country with special reference to its mineral resources. The results will be considered under two general heads: Part I, Historical and Structural Geology; Part II, Economic Geology.

PART I.

HISTORICAL AND STRUCTURAL GEOLOGY.

ROUTE OF TRAVEL.

A camping party, consisting, besides the writer, of an assistant, a packer, and a cook, outfitted a pack train at Forest Grove, west of Portland, in Washington County, and crossed over the divide to the coal fields of the Upper Nehalem, east of Vernonia, in Columbia County. The route, which is indicated upon the map, Pl. I, continued down the river to beyond Mishawaka and crossed the military trail by way of Saddle Mountain to Astoria. The coast roads and trails were followed south to the Lower Nehalem coal field and Tillamook, where the party divided to return to Forest Grove by different routes, F. M. Anderson crossing the range by the Trask River stage road, and the writer, with the main party, returning by way of Wilson River.

Starting from Forest Grove a second time, the party moved by wagon, camping by the way, to Corvallis, and crossed the Coast Range to the Yaquina coal field and the coast, returning to Corvallis by the Elk Creek road. The route continued southward to Harrisburg, where the party was in part disbanded and gave up camping to live with the people. Work was continued in the vicinity of Roseburg and westward along the several roads to the coal fields of Coos Bay.

TOPOGRAPHY OF WESTERN OREGON.

Along the coast of Oregon and California, from the Columbia to near the boundary of Mexico, there is a prominent range of mountains known generally as the Coast Range. The essential continuity of this range, as well as its distinctive parts, was long since pointed out by Professors Dana [1] and Newberry.[2] In middle California and northern Oregon, where the range is bounded on the east by a great valley, it is distinct, and these portions are readily distinguished, respectively, as the Coast Range of California and the Coast Range of Oregon. But between them, in northwestern California and southwestern Oregon, there is a large complex group of mountains, in which the Cascade, Sierra Nevada, and the Coast Range appear to meet. This irregular group contains many individual ridges and peaks, as, for example, Yallo Bally, Bully Choop, Salmon, South Fork, Trinity, Eddy, Scott, and Marble Mountain in California, as well as Siskiyou, Rogue River, Umpqua, and other mountains in Oregon. Upon geological grounds it appears that this group of mountains belongs to the Coast Range rather than to the Sierra Nevada or Cascade Range, and needs a special name to distinguish it from the Coast Range of Oregon on the north and the Coast Range of California on the south. For this reason this group has been designated the Klamath Mountains, after the principal river which cuts through these mountains to the sea.

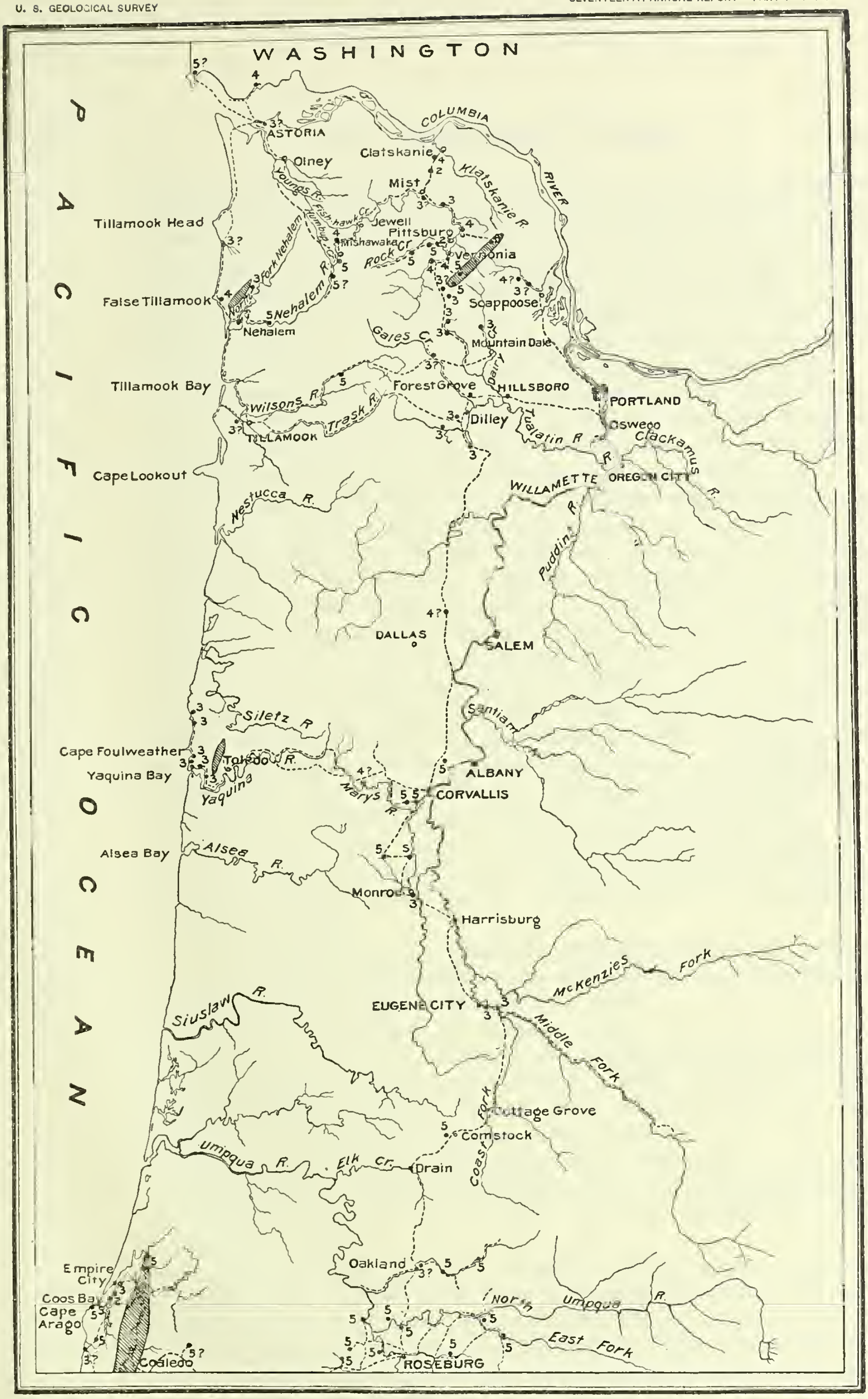
The Klamath Mountains of Oregon extend northward from the southern boundary to about the Middle Fork of the Coquille. Beyond that point the Coast Range of Oregon stretches away to the Columbia.

The reconnaissance outlined in these pages extended throughout the Coast Range of Oregon and touched at a few points upon the northern border of the Klamath Mountains and the western foot of the Cascade Range. In the accompanying map, Pl. IV, the route is illustrated.

FEATURES OF THE COAST RANGE OF OREGON.

The Coast Range of Oregon is an irregular ridge or series of ridges with bold lateral spurs, especially on the ocean side. It varies much from place to place, yet nowhere does it attain a great altitude. The elevations of its summits have not yet been accurately determined anywhere, and only in a few places has the height of peaks been even approximately measured. Saddle Mountain, which is a rugged summit seen to the southeast from the Astoria, has a bold peak outlined against the sky, and attains an altitude (aneroid) of over 3,325 feet. Of this view Professor Dana [1] remarks that "there was one broken summit to the southeast, calculated to engage the attention; it is called by the Indians Swàlalàhos, and has also been named Saddle Hill."

[1] Wilkes Exploring Expedition, Vol. X, p. 615.
[2] Pacific Railroad Survey, Vol. VI, Pt. II, p. 29.



MAP OF NORTHWESTERN OREGON, SHOWING ROUTE.

The route of travel is indicated by a broken line. The dark-lined inclosed areas represent coal fields. The numbered dots indicate localities where fossils were found; 1 = Pleistocene, 2 = Pliocene, 3 = Miocene, 4 = Oligocene, 5 = Eocene.

Onion Peak, farther westward, is of nearly equal height. Both are old volcanoes and belong to the volcanic ridge which runs transverse to the general trend of the Coast Range. As shown in Pl. V, it begins at the west, in the Ne ah kah nie Mountains, just north of the mouth of the Nehalem, and stretches northeast through Union Peak, Saddle Mountain, and other summits, to the Columbia, near Westport. The bold escarpment of the north bank of the Columbia at this point belongs to the same line of elevations extending into Washington.

A noteworthy feature of this ridge, especially about Saddle Mountain, and to a less extent also through portions of the Coast Range, is the occasional occurrence of comparatively even table-lands, above which the peaks and upper mountain slopes rise rather abruptly.

At the head of the Nehalem is Round Top, and farther south, on the Trask, is Larch Mountain, which was reported to Mr. Anderson as being 3,500 feet high. Euchre Peak, near the head of the Siletz, according to Mr. C. B. Crosno, of Toledo, is probably the highest peak of the range, and attains an altitude of 3,962 feet. Marys Peak, south of the Yaquina, is prominent, as seen from the eastward near Corvallis, and in elevation may be nearly equal to or even greater than any of those already mentioned. Farther southward the Coast Range touches the Calapooia Mountains, a spur of the Cascade Range, and on the Coquille passes into the Klamath group. The general elevation of the mass and its tabular feature increase southward, but individual peaks are less prominent. Throughout its whole length the slopes of the Coast Range in Oregon are of unequal length. The watershed lies nearest the eastern side of the range. The spurs running out from the summit of the range to the sea are long and of gentler descent than the shorter spurs, which extend toward the Willamette Valley.

At two points in its course, between the Columbia and the Coquille, the Coast Range is transsected by rivers—the Nehalem near the northern end and the Umpqua in the southern third.

The Nehalem rises upon the eastern slope of the Coast Range, and by a fine curve of over 50 miles to the northward it returns against the range and in a southwesterly direction cuts through it, near the Saddle Mountain ridge, to the sea. The stream is small, and the canyon it has cut across the range is deep and long.

The Umpqua is a larger stream, deriving much of its water from the Cascade Range. It flows northwesterly to near the Calapooia Mountain, where it turns abruptly westward and cuts through the Coast Range to the ocean.

At two other points there are low gaps across the range. One is at the head of the Yaquina River, where the Oregon Central and Eastern Railroad crosses the summit at an elevation 720 feet above low tide in Yaquina Bay; and the other is on the Suislaw, which practically cuts entirely through the Coast Range, but reaching the point where that range touches the Calapooia Mountain, it fails to meet a low valley. The eastern base of the range at Summit, on the Oregon and California Railroad, between Cottage Grove and Drain, has an elevation of 779 feet.

FEATURES OF THE OREGON COAST.

The coast of Oregon is made up of long stretches of sand beach, interrupted here and there by prominent headlands of hard. igneous rocks, which stand out boldly to sea as if to defy the waves and impede coastwise traffic.

The beaches are remarkable for their solidity and beauty, as well as their strong, cool, summer winds which afford complete relief from the heat of the interior valleys. Clatsop Beach, along the northwest shore of the county of the same name, and Nye Beach, near Yaquina Bay, are the most frequented, and are justly celebrated on account of the attractive camps which their clustered pines afford.

Clatsop Beach is especially remarkable on account of its sand ridges, which extend with striking uniformity for nearly a dozen miles along the coast, and carry the Necoxey River for almost the whole distance to the beach. Nearly midway between Astoria and Seaside the profile of these ridges appears as in fig. 4.

The road runs along the crest of the ridge and affords a fine view. There are usually three ridges, nearly parallel and remarkably even and regular. They are composed, at least in large part, of sand, and are covered by a dense growth of grass and ferns. The western

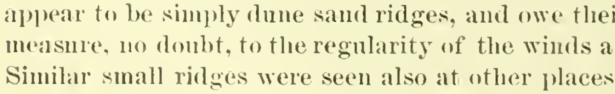


FIG. 4.—Section across dune ridges of Clatsop Beach.

slopes are gentle, but to the landward the incline is 40 degrees. The first ridge is one-third of a mile from the beach, above which it rises about 30 feet; the other two are not quite so high nor so regular. They appear to be simply dune sand ridges, and owe their regularity in large measure, no doubt, to the regularity of the winds and the sand supply. Similar small ridges were seen also at other places, but they were less regular and extensive. Several miles north of the mouth of Tillamook Bay such ridges inclosed lakes of considerable size close to the beach, and the only outlet was by filtration through the barrier.

The picturesque features of the coast are found not so much in its beaches as in its headlands. Of these, Tillamook Head, False Tillemook, and Meares Point are good examples. All are composed of igneous rocks, with cliffs against the surf, which break the continuity of the beach in each case for several miles. The northern end of Meares Point is shown in Pl. VI. A sheet of columnar basalt occurs near high-tide level, and enables the waves to cut out caverns of considerable dimensions. These in time enlarge and join, forming arches which when broken leave pillars and ledges, such as are seen on the right in the illustration, to mark the line of an earlier cliff.

NE AH KAH NIE MOUNTAIN, ETC., MOUTH OF NEHALEM RIVER.

The only headland of sedimentary rock seen on the coast by the writer is Otter Rock, which is composed of thin-bedded, yellowish Miocene sandstone. It is firmer than its neighbor, and sternly resists the dash of the waves, but is gradually giving way under their unceasing attack. One of its principal ledges, 40 feet above the water, is in places full of holes, made by the rock oyster at a time when the land stood 40 feet lower than now. Potholes are common on the surface, and from the north side a cave enters the rock, its roof having tumbled in and formed a great pit, known as the Caldron. It is 40 feet deep and of equal diameter. The débris at its bottom is swept away by the waves, and at low tide it can be entered from the beach.

HISTORICAL NOTES.

The earliest definite information concerning the geology of that portion of the country indicated as belonging to the Coast Range of Oregon is contained in the report of Prof. James D. Dana,[1] who accompanied the Wilkes exploring expedition. He collected a number of Miocene fossils from the shales and sandstones upon the banks of the Columbia River, near its mouth, and ascended the volcanic peak of Saddle Mountain. On the land tour from the Columbia River to San Francisco, Cal., between the head of the Willamette Valley and the broad plain of the Sacramento, he passed in some places along the eastern border of the Klamath Mountains, and at others the route lay within the eastern portion of that group.[2] He fully recognized the fact that they are composed chiefly of ancient granitic, hornblendic, and talcose rocks, besides some later sedimentary and igneous rocks.

Prof. J. S. Newberry[3] in 1855, as geologist to Lieut. R. S. Williamson's party of the Pacific Railroad Surveys, passed through the Willamette Valley and across the Siskiyou and other portions of the Klamath Mountains, following much the same route as that of Professor Dana a few years before. He writes as follows (p. 29):

> The continuity of the present Coast Mountains of California and Oregon can scarcely be doubted. The fossiliferous sandstones of Monterey, Santa Clara, San Francisco, Port Orford, Coos Bay, Astoria, and the Cowlitz are all of the same age. Though presenting marked local peculiarities, they have a common character, both in their lithological features and in their fossils, and are to be referred to a common period—certainly not older than the Miocene.
>
> As far north of San Francisco as Cape Mendocino the Coast Mountains have the same general northwest trend, and a more plausible supposition than that the Cascade formed the continuation of the Coast Mountains would be that the latter ranges terminate at Cape Mendocino and that the Coast Ranges of Oregon were a continuation of the Sierra Nevada. It is not necessary to suppose this, however, but it is

[1] United States Exploring Expedition, 1838-1842, under command of Charles Wilkes, Vol. X, Chap. XVII, pp. 611-678.

[2] The mountains between the south fork of the Umpqua and the Sacramento Valley, according to Professor Dana, were the Umpqua Mountains and the Shasty Mountains. That portion of the Shasty Mountains near the boundary of Oregon and California Professor Dana called the Boundary Range. It is now generally known as the Siskiyou Mountain.

[3] Pacific Railroad Surveys, Vol. VI, Pt. II.

sufficient to consider the Coast Mountains of Oregon as the Coast Mountains of California deflected from the trend which they preserve below Cape Mendocino, and that the ranges of the coast and of the interior inosculate on either side of the parallel 42° in Calapooya, Umpqua, and Siskiyou Mountains.

The most important contribution of Professor Newberry to the geology of the Coast Range of Oregon is the announcement of the Miocene at Coos Bay, where it is said to contain valuable deposits of coal.

Prof. Henry D. Rogers,[1] upon a general geological map of the United States, in 1855 represented the Coast Range of Oregon, including the Klamath Mountains, as being made up chiefly of Miocene strata, inclosing 13 small isolated areas of volcanic rocks, distributed along the central portion from Saddle Mountain to the Umpqua.

In the same year (1855) Jules Marcou[2] published a map of the United States, upon which the Coast Range of Oregon, from the Columbia to the Klamath River, is represented as composed of Tertiary rocks, excepting about Coos Bay, where, on account of the coal, the Carboniferous is supposed to occur. Eruptive and metamorphic rocks are indicated from the upper portion of the Willamette Valley and the mountains on the coast near the Oregon and California line.

W. P. Blake[3] and Prof. J. S. Newberry, the next year, called attention to the fact that all the evidence thus far obtained indicated that the Coos Bay coal was of Tertiary and not of Carboniferous age.

In 1857 Prof. James Hall[4] and J. P. Lesley issued a geological map representing the Coast Range, from the Columbia River into California, as made up chiefly of a continuous mass of lava and igneous rocks, with Quaternary borders along the principal rivers of the coast. The Cascade Range is supposed to have a core of metamorphic rocks connecting it with the Sierra Nevada.

Prof. C. H. Hitchcock and W. P. Blake published three geological maps[5] of the United States; upon all of them the Coast Range of Oregon is represented as a continuation of the Sierra Nevada of California, and composed essentially of the same Eozoic and metamorphic rock. Upon the first two of these are areas of Cretaceous marked upon the Rogue and Illinois rivers, but these are omitted from the last edition.

About this time (1874) Professor Condon was appointed State geologist of Oregon and began a more continuous study of the geology of the Coast Range. In June, 1880, through Prof. E. D. Cope, the follow-

[1] Geological Map of the United States, Keith Johnson's Physical Atlas, p. 8.

[2] Carte géologique des États-Unis et des provinces anglaises de l'Amérique du Nord, Annales des mines, 5th ser., Vol. VII, p. 321, Pl. IX.

[3] American Journal of Science, November, 1856, Vol. XXII, 2d ser., p. 3. Blake also refers to Newberry as follows: Proceedings of the American Association for the Advancement of Science, Albany, 1856.

[4] Map illustrating the general geological features of the country west of the Mississippi, accompanying Report on the United States and Mexican Boundary Survey, by W. H. Emory.

[5] Geological map of the United States compiled for the Ninth Census, 1872. Geological map of the United States accompanying the report of R. W. Raymond, United States Commissioner of Mining Statistics, 1873. Geological map of the United States, in Walker's Statistical Atlas, 1874, Pls. XIII and XIV.

NORTH SIDE OF MEARES POINT.

ing note, entitled "Corrections of the geological maps of Oregon," was published:[1]

In the existing geological maps of Oregon the Coast Range is represented as composed of Archean rocks. This is a serious error. Professor Newberry has already stated (U. S. Pacific R. R. Surveys, Vol. VI, Pt. II, p. 29) that the fossils of the range are of an age not older than the Miocene. The unpublished notes of Professor Condon, formerly State geologist, state that the backbone of the Coast Range consists of argillaceous shales, which contain invertebrate and vertebrate fossils, frequently in concretions. Some of the latter are Physoclystous fishes, with strongly ctenoid scales. To this formation Dr. Condon gives the name of Astoria shales. Above this is an extensive Tertiary deposit, rich in Mollusca, which is usually interrupted by the central elevations of the mountain axis. Professor Condon refers this to an upper Miocene age, under the name of the Solen beds. On the flanks of the mountains this is overlain by a Pliocene formation, containing some of the fossils of the Equus beds of central Oregon. This is both underlain and overlain by basalt and other volcanic products.

C. H. Hitchcock[2] published his large wall map of the United States in 1881. The geology of the Coast Range of Oregon was furnished by Professor Condon, who represented the distribution of the various formations in much greater detail than had been done previously. The mass of the range, according to the map, was supposed to be formed of Cretaceous sediments with large isolated tracts of volcanic rocks, stretching from the crest of the range toward the sea. Middle Tertiary strata are shown upon the flanks of the range, and perhaps also some older Tertiary. The two colors used to designate them can not certainly be distinguished upon the map examined by the writer.

In 1886, C. H. Hitchcock compiled for the American Institute of Mining Engineers a geological map of the United States, which, so far as the Coast Range of Oregon is concerned, follows the large map of 1881, and represents the backbone of that portion of the Coast Range as Cretaceous, with fringes of Miocene upon its flanks.

Dr. C. A. White announced the discovery by Professor Condon of strata containing characteristic Eocene fossils at Albany[3] in the Willamette Valley, and at Cape Arago,[4] and discussed the possible occurrence of Eocene strata near Astoria. In his correlation paper on the Cretaceous[5] is given a map showing the backbone of the Coast Range from the Columbia to near the latitude of Coos Bay to be of Cretaceous rocks, and in this respect the map agrees with the last edition of Hitchcock's map.

Dr. W. H. Dall[6] and G. D. Harris published a summary of the state

[1] Am. Naturalist, June 1880, Vol. XIV, p. 457.

[2] In the pamphlet, by the same author, to accompany the map, it is stated, on page 28: "For this region (Oregon) we had a manuscript map colored for us by Professor Condon, and it was our lot to collect some additional information personally on the trip up the Columbia River and across the Blue Mountains. I understand that the distinction between the volcanic and the crystalline is not maintained in the Coast Range, and that some of the Cretaceous rocks in the southwest corner may be crystalline."

[3] Bull. U. S. Geol. Survey No. 18, 1885, pp. 7–9.

[4] Bull. U. S. Geol. Survey No. 51, 1889, pp. 29–32.

[5] Bull. U. S. Geol. Survey No. 82, 1891, p. 286.

[6] Bull. U. S. Geol. Survey No. 84.

of knowledge concerning the Neocene of the United States in 1891. The map showing the distribution of the Neocene formations, based largely upon information from Professor Condon, represents the Coast Range of Oregon as having a fringe of marine Neocene upon both flanks from the Columbia to the Siuslaw. The central portion of the range to the northward, and the whole of the range south of the Siuslaw, excepting at Coos Bay and Cape Blanco, are left uncolored, meaning thereby nothing more than the absence of the Neocene within the uncolored areas. They describe the Astoria group as consisting of Astoria shales and Astoria sandstone, and mention the Aturia bed at Astoria as well as the Miocene near Eugene City, in the Willamette Valley.

Dr. G. F. Becker[1] and the writer,[2] in 1890, recognized the lower Cretaceous at Riddle, Oreg., and in later years the wider distribution of these beds[3] was recognized and discussed by the writer, who considered also the Eocene (Tejon) and described its areal extent, as well as its unconformity to the Shasta-Chico series.

The latest publication[4] by the writer touching upon the geology of that region contains a preliminary geological map of the Klamath Mountains, on which the general distribution of the Eocene southwest of Roseburg is represented. In a cover pocket of the same volume is included a reconnaissance map of the United States, showing the distribution of the geologic system as far as known, by W. J. McGee, in 1893. The outlines of the Miocene in the Willamette Valley and on the coast and of the Eocene at Corvallis and along the Umpqua north of Roseburg were drawn by the writer under the immediate direction of Professor Condon, who thus contributes the first definite knowledge concerning the general section of the Coast Range of Oregon.

GEOLOGICAL FORMATIONS.

PRE-CRETACEOUS.

Tupper Rock, near Bandon, at the mouth of the Coquille, is made up of blue schistose rocks, which, in places, contain numerous small brick-red grains.

The mass is composed chiefly of a blue mineral, which is strongly pleochroic, ranging from colorless through reddish violet to sky-blue, with the characteristic cleavage and low angle of extinction that belong to the blue hornblende, glaucophane. Besides the prismatic planes, the clinopinacoid is sometimes well developed. The glaucophane includes numerous small particles of a colorless mineral. Between the prismatic grains of glaucophane are clear ones, apparently of quartz, which are not readily detected on the broken surface

[1] Bull. Geol. Soc. America, Vol. II, pp. 203–205.

[2] Ibid., p. 207–208.

[3] Bull. Geol. Soc. America, Vol. IV, 1893, pp. 205–224; Bull. Geol. Soc. America, Vol. V, 1894, pp. 435–464.

[4] Fourteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1894, p. 414.

of the rock, even with a lens. Occasionally the mass includes garnets, reddish on the weathered surface, but sometimes greenish on a fresh fracture. This is due apparently to the fact that near the garnet the hornblende is generally green, although some of it included in the garnet has the pleochroism of glaucophane. A short distance from the Tupper Rock is another, which is composed of a greenish, indefinite rock, whose composition and relations are in doubt. Among the ledges upon the beach, most of which are sandstones ranging from a compact form like basalt to fine conglomerate, there are outcrops of a greenish rock, which, from the fact that it contains numerous lath-shaped feldspars with much chlorite, evidently derived by alteration from some other ferro-magnesian silicate, is clearly of igneous origin. The sandstones are much disturbed, but in at least one place they appeared to dip beneath the glaucophane schist. The exposures here, upon the seaward side, are good, and it seems probable that by detailed study the origin of the glaucophane schist may be determined. The presence of both igneous and sedimentary rocks suggests that, as shown by F. Leslie Ransom,[1] for the glaucophane schist of Angel Island, it may be a product of contact metamorphism

The age of the glaucophane schist and the associated sandstone near Bandon is not known, although it is supposed that they are older than the Cretaceous, from the fact that in the neighborhood of Roseburg glaucophane and other schistose with jaspery rocks appear to be unconformably overlain by the Cretaceous. In the same region limestones occur which are occasionally oolitic, and they contain traces of fossils. Mr. T. W. Stanton, to whom they were referred with a lot of Cretaceous fossils, reports that these have been examined by both Mr. Schuchert and himself without finding any definitely determinative fossils in them. He adds: "There are, however, some indications that they are Paleozoic rather than Mesozoic, in the presence of large cylindrical, crinoid columns and of two very imperfect columns that have a Paleozoic aspect, though the genera are not determinable."

Although these older stratified rocks form scarcely an appreciable portion of the Coast Range of Oregon—that is, the part north of the forty-third parallel—they rise in mass with many varieties and become a prominent feature of the Klamath Mountains. These older rocks have various forms of eruptives associated with them. Some of these are doubtless older than the Cretaceous, others may be younger, and the third class is certainly younger. The occurrence of some of the eruptives of this doubtful middle period in several rocks of the range suggests that there may be an irregular ridge of older rocks concealed beneath the newer ones, which form the mass of the range. At one time, as mentioned in the "Historical notes," it was supposed that these ancient rocks of the Sierra Nevada entering Oregon turn northerly along the coast and form the greater portion of the Coast Range. But

[1] Bull. Univ. of California, Department of Geology, Vol. 1, Geology of Angel Island, pp. 193–240.

that opinion must be abandoned, as it is quite improbable that pre-Cretaceous sedimentary rocks form any considerable portion of the Coast Range in Oregon north of the Coquille. So far as evidence is known, it indicates that they do not enter into the composition of this part of the range.

CRETACEOUS.

On a number of geological maps, as already indicated, the Coast Range of Oregon was marked as being composed chiefly of Cretaceous rocks. This is far from being the fact, for no certain Cretaceous rocks are known in the range, and yet it is probable that they do occur where it joins the Klamath Mountains. South of Roseburg a short distance, along Myrtle Creek, are Cretaceous conglomerate sandstones and shales, resting upon the older rocks, from which they were derived. That these sedimentary rocks belong to the Cretaceous is clearly indicated by the form of Aucella and other fossils which they contain. In the Coast Range, at several points along the new stage road between Myrtle Point and Remote, there are similar rocks, and it is probable that they belong to the Cretaceous, although no fossils have yet been found in them. They unconformably underlie the Eocene sandstones which form the mass of the Coast Range where it abuts against the Klamath Mountains, and are not seen as far north as the Middle Fork of the Coquille.

EOCENE.

One of the most important contributions to the areal geology of northwestern Oregon made by this reconnaissance is the recognition of a large tract of Eocene forming the mass of the Coast Range from near the Columbia to the Coquille. While it is possible that the Miocene strata may in places, especially toward the northern end, form a considerable portion of the range, they are of far less importance, so far as bulk and area of exposure are concerned, than the Eocene strata.

The rocks of Eocene age belong in part to each of the two groups, igneous and sedimentary rocks. Those of the first group, although much altered, are chiefly basalt and associated tuffaceous materials. To the second group belong the shales and sandstones. The rocks of these three geological divisions are not clearly distinct, being more or less interstratified, but in general the oldest Eocene strata are those composed of volcanic material, and they are closely associated with the lavas to which they belong. Next above them comes a great mass of shales, containing here and there much material of igneous origin, and in the upper part of the series massive beds of sandstone predominate. For convenience, these three groups will be considered separately.

IGNEOUS SEDIMENTS.

These are best exposed upon the Nehalem River, in Klatsop County, about 2½ miles below the mouth of Humbug Creek. The slopes of the canyon through which the river runs, from a few miles below Mishawaka for about 20 miles toward its mouth, are formed largely of basic igneous rocks. They occasionally form rapids in the stream.

Associated with these eruptives are tuffaceous sandstones, which occasionally contain conglomeratic portions with small, often angular, pebbles. The material appears as if originally ejected from a volcano rather than derived by erosion from the rocks with which it is associated, and would therefore be essentially contemporaneous with the volcanic eruptions. It contains a few fossils, among which Dr. Dall recognized Tayloriana Gabb; *Modiola multiradiata* Gabb; *Modiolaria* n. sp., besides Ostrea (?), Callista, and Dentalium, and regards them as Eocene (?).

Near Felix Roy's, on the Nehalem River, about 5 miles east of the Nehalem post-office, Mr. Anderson observed much conglomerate of eruptive material and a heavy bed of tuff, from which were collected, according to Dr. Dall, Ostrea, *Modiola ornata* Gabb, *Modiola cylindrica* Gabb, *Septifer dichotomus* Gabb, and *Turritella uvasana* Conr., which he regards as Eocene.

Igneous rocks which closely resemble those seen on the Nehalem occur on the north bank of the Columbia opposite Astoria and near Ilwaco. At Meglers Landing, in that region, the tuff contains fragments of Ostrea, Dentalium, and casts of a gasteropod, but nothing characteristic was found. These beds, however, appear to underlie unconformably the Aturia beds which occur farther eastward.

From Tillamook there are two stage roads across the mountain to the Willamette Valley, one by way of Wilson River and the other by the Trask. Both streams cut deep canyons down the western slope and expose a great mass of igneous rocks, which form the greater part of the range. They reach to the foot of the range, only 5 miles from Tillamook Bay. At the mouth of the Wilson River Canyon the rock is chiefly conglomerate, of waterworn volcanic material like that against which it rests. Farther up the canyon, near the mouth of Fall Creek and at several other points, shales and sandstones were noted among larger masses of volcanic rocks. About 22 miles from Tillamook, a short distance below Smith's, on the Wilson River toll road, and also near by on the river, the rocks are found to be fossiliferous, containing *Turritella uvasana*, as well as Ostrea, Pecten, Nucula, and Hipponyx, and other forms not definitely determinable. There appears to be no doubt as to their Eocene age.

Proceeding southward, the next locality of volcanic sediments noted was at Vineyard Hill, 4 miles north of Corvallis, where a more or less amygdaloidal eruptive like that of the Nehalem occurs, and in the sediments associated with it are found a few fossils, discovered by the enthusiastic local geologist Mr. John Ray. Not enough fossils were gathered to fully establish the age of these beds, but in the shales immediately to the eastward, about Howes, characteristic fossils, as

Modiola ornata Gabb, with others, have been found by Mr. Ray, and there can be little, if any, doubt concerning the age of the volcanic sediments of Vineyard Hill. They extend westward, cropping out here and there, possibly as far as Blodgetts Valley, where Mr. Anderson collected fragments of *Aturia angustata*, Ostrea, Pecten, Cardium, and Leda, which Dr. Dall referred without doubt to the Oligocene. They are confined to the eastern portion of the range, and in the section afforded by Marys River do not extend to the summit. Similar strata occur also at Monroe, 18 miles south of Corvallis, but they are not fossiliferous.

The same general sort of basic igneous rocks occur about Roseburg and at several points on the western side of the Coast Range on the road to Coos Bay, but so far as yet known the only sediments of such material in the Coos Bay region occur on the east coast opposite North Bend. The tuffaceous sandstone dips 40° to the westward, and is overlain by shales and sandstones having a gentler dip but rich in Eocene fossils.

The age of the eruptives associated with the Eocene beds composed of the same material is in many cases not definitely known. While some of them are essentially contemporaneous, it is possible that others may be older, but of this the evidence is not yet conclusive.

SHALES.

Arago beds.—On the Washington shore of the Columbia near Ilwaco is a prominent hill of dark-gray shales capped by a bed of Pleistocene sand. The shales look somewhat like those of Astoria, but their strike is N. 39° E., dipping 35° to the northwest, and so far as their position indicates, there is no continuity with those of Astoria. The fossils determined by Dall in this locality are Calliston sp., Dentalium n. sp., and Modiola like tulipa Lam. which he with doubt referred to the Eocene.

Some of the best exposures of the Eocene shales observed are upon Rock Creek from 6 to 10 miles above Vernonia, in Columbia County. At several points there are cliffs of shale containing large concretions and thin, sandy layers. The latter under microscopic examination proves to be composed almost wholly of material derived either directly from volcanoes or by erosion from igneous rocks. The shales weather gray, but on a fresh fracture are dark, containing much vegetal matter. They strike N. 82° E., and dip very gently to the southeast, away from the older rocks in the region of the Rock Creek mines. From the fossils collected at this locality Dr. Dall reports Nucula sp., *Liocardium linteum* Conr., *Tellina hoffmaniana* Gabb, *Cylichna cf. costata* Gabb, *Macoma* n. sp. (?), and *Turbo* (?) n. sp., from one bluff, while *Yoldia cf. montereyensis* Dall, *Cassadaria* (=*Phalium*) *turberculata* Gabb, and a number of other forms, most of which are known, come from another bluff. The former are referred, apparently without doubt, to the Eocene, but the latter are referred to the Eocene or Oligocene. In the field these shales were considered to be the lower part of the series exposed on the Nehalem at Wilsons Bluff, from 1 to 3 miles above Vernonia, where a number of Oligocene fossils were found.

One of the most interesting Eocene exposures occurs farther down the Nehalem, in Clatsop County, at the fording nearly midway between Jewell and Mishawaka. At this point about 60 feet of shales are exposed, with some arenaceous beds of igneous material. The shales have rather large concretionary masses, and strike N. 22° W., with a dip of 15° SW. In the shales and concretions numerous fossils are found, of which Dr. Dall reports the following: Crab, coral, *Dentalium* n. sp., *Yoldia* n. sp., *Thracia* n. sp., *Verticordia* n. sp., *Cardium breweri* Gabb (?), *Liocardium linteum* Conr., *Lyonsia* n. sp., *Bela* n. sp., *Fulgur* (?) sp., *Heteroterma trochoidea* Gabb (?), *Rimella canalifera* Gabb, *Urosyca caudata* Gabb, *Pyrula tricostata* Lam., *Ampullina* sp., *Scaphander* n. sp., and *Aturia angustata* Conr.

Notwithstanding the presence of Aturia, which is a characteristic Oligocene form, Dr. Dall refers these fossils to the Eocene. The Aturia found here is the largest specimen seen during the reconnaissance, much larger than any of those collected in the Oligocene, and it is not improbable that Aturia reached its greatest development before the close of the Eocene.

South of Columbia County, on the east side of the Coast Range, these shales were not seen in Washington, Yamhill, or Polk counties. The first outcrop noted is 5 miles north of Corvallis, near Benson's and Howe's, where, at localities pointed out by Mr. John Ray, *Modiola ornata* Gabb, *Solen parallelus* (?), *Nucula truncata* Gabb, *Tellina remondi* Gabb, and other forms were collected.

Near Corvallis Mr. John Ray has collected numerous fossils and gathered much information concerning their distribution. His collection is confined to Benton County, and is deposited in the State Agricultural College at Corvallis. Under his guidance a number of Eocene forms were obtained, not only from the shales near Benson's and Howe's, east of Vineyard Hill, but also from the more sandy layers near Scott's, Cooper's, and Newton's, a few miles southwest of Corvallis. The strike of the strata of that region is approximately north and south and the dip easterly. The same formation continues to the southwest, and is full of fossils. Near Rogers's, in sec. 27, T. 13 S., R. 6 W., where the strike is nearly east and west and the dip about 20° to the northward, Venericardia occurs, with an abundance of other fossils, in a ledge of sandstone, of which a thickness of about 30 feet is exposed.

Four miles directly east of Rogers's, at the foot of Coon Hill, on Foster's upper place, above a shaft sunk in prospecting for coal, is a soft fossiliferous sandstone that strikes north and south and dips westerly. The specimens of *Venericardia planicosta* Conr. and casts of Modiola found here show that the rocks belong to the Eocene. The discordance in position at the last two localities may be due to the intrusion of igneous rocks, by which they are separated.

A few miles farther southward, near Monroe, the Eocene beds continue to be fossiliferous, and in the John Ray collection from this locality Mr. Anderson determined *Cardita planicosta*, *Galerus excentricus*, *Modiola ornata*, and other forms. In Long Tom Creek, at Monroe's, a low arch of tuffaceous sandstone is exposed, and appears to run under the strata of the hills a short distance to the westward. The sandstone in the quarry by the road close to Monroe's is sparsely fossiliferous, and according to Dall the forms are Miocene. They dip gently eastward, and the Eocene beds must lie some distance to the west.

The distribution of the Eocene strata from Corvallis to Monroe's shows that they extend directly south parallel with Long Tom Creek, and this opinion is confirmed by the appearance of *Venericardia planicosta* and other Eocene forms near Comstock, on the railroad between Drain's and Cottage Grove. The dark fossiliferous shales near Comstock have been prospected for coal, but thus far without profit. The prominent hill northwest of the station is of sandstone overlying the shales, and affords an excellent view to the westward. Fossils have not been found in the sandstone, and its relation to the underlying shales is not certainly known. Its topographic relations indicate that it is the same sandstone which forms the prominent escarpment of the range from Tyee Mountain to Camas. Fossils have not been found in the massive sandstone along this bold front, but at a number of points they have been collected in the underlying beds, chiefly shales, as, for example, in Douglas County, at Cleveland, and near Callahan's, in the upper portion of the French settlement (secs. 9 and 15, T. 27 S., R. 7 W.), and in Camas. All of these are of Eocene age, and it seems probable, as will be noted later, that the sandstone itself is Eocene.

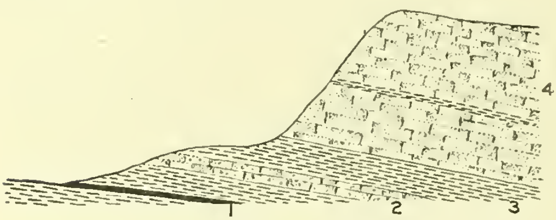


FIG. 5.—Section from Callahan's westward to crest of Coast Range. 1, Coal; 2, Fossiliferous sandstone; 3, Shale; 4, Sandstone.

Opposite Callahan's a trail ascends this rugged front, and the section, fig. 5, illustrates the relations of the exposed strata.

At Callahan's is coal (1) and the fossiliferous beds (2 and 3), which are clearly Eocene. They are chiefly shale, but contain occasionally sandstones and rarely calcareous nodules of considerable lateral extent. At one place they have been burned for lime. The basal portion of the mountain is generally covered by slides of soft sandstone from above, but the only rocks seen in place were shales. The upper half of the mountain is sandstone, having a thickness of about 1,000 feet. Its distribution will be considered after the description of the underlying shales has been completed. There is no reason to suspect that the heavy sandstone at the top of the series overlies the shales unconformably in this section, but at several other localities such discordance is indicated. However, in these cases the underlying beds may not be of Eocene age. The difference in altitude between Callahan's and the crest is nearly 2,000 feet. The dip of the strata is about 8° to the northwest, and the whole thickness of strata exposed above Callahan's is probably not less than 3,500 feet.

East of the Coast Range, between the Callapooia and Rogue River mountains, in the irregular valley drained by the forks of the Umpqua, the Eocene shales, with their interbedded sandstones, have a wide distribution, and fossils occur in many places. They are especially abundant about 20 miles northeast of Roseburg, near the mouth of Little River, where the characteristic *Venericardia planicosta* occurs, and the strata contain some beds of coal.

On the coast of Oregon outcrops of Eocene strata are not known north of Cape Arago, but at that point, as long since made known through the observations of Professor Condon, highly fossiliferous sandstones and shales are well exposed. They strike about N. 10° W. and dip 60° to 70° to the northeast. These beds are largely shales, but numerous sandstones occur, most of which are thin, although some are heavy enough to form prominent bluffs and points projecting to the water's edge. East of Cape Arago these highly inclined Eocene strata are exposed continuously along the beach for several miles, and it is evident that their thickness is very great. These fossiliferous strata are well exposed along the road immediately north of Marshfield, and also at Jordan Point, on the eastern side of the bay, where they rest upon a mass of older tuffaceous material. Judging from their position, one would say that they include the valuable coal beds of that region, but as the fossils found in immediate connection with the coal are not characteristic, the evidence is not yet conclusive.

Among the fossils found in the beds at Cape Arago, Dr. Dall reports the following:

Modiola ornata Gabb.
Venericardia planicosta Lam.
Pectunculus veatchii Gabb.
Turritella uvasana Conr.
Species of Thracia, Diplodonta, Callista, and Leda.

One mile east of the cape, in the same series, were found:

Callista n. sp.
Mactra darienensis Dall
Chione sp. n.
Cyclina n. sp.
Modiola ornata Gabb.

And at Jordan Point:

Turritella uvasana Conr.
Ampullina sp.
Lunatia eminula Conr.
Pleurotoma n. sp.
Dentalium (2) n. sp.
Tellina remondi Gabb.
Yoldia, Leda, Solen, Tellina, and Callista.

On account of the fact that this series of beds is so well exposed at Cape Arago and contains characteristic fossils relegating them definitely to a position high up in the Eocene, they are called the Arago beds.

About a mile east of Cape Arago the Arago beds contain a small layer of coal and thin seams or lenses of limestone; some beds of sandstone also occur here and there in the shales. This series of highly inclined strata extends eastward from the cape to the vicinity of Coos Head, where it is in all probability overlain unconformably by the massive Miocene sandstones which dip gently (18°) to the northeast. In the season of low tides it is said that a person can easily follow the beach from South Slough to the cape, but at the time the writer was there the water, even at low tide, was so high that about a mile of the beach near Coos Head was impassable. The contact of the Eocene and Miocene occurs along that portion of the beach. It is doubtless well exposed in the bluff, and the discordant positions of the strata at the points where they are seen nearest together strongly suggest a conspicuous unconformity between them.

To the southward from the cape the Arago beds extend along the coast to near the mouth of the Coquille, where the older crystalline rocks appear. *Turritella uvasana* Conr. was found in the shales of Five-Mile Grade (sec. 3, T. 27 S., R. 14 W.), and in a bluff by the road near Lampers Landing on the Coquille numerous characteristic Eocene forms occur in the sandstone and shales. In the valley of the Coquille, after leaving the older crystalline rocks at Bandon, sandstones outcrop with occasional shales much of the way to Myrtle Point, where a larger outcrop of dark shales with calcareous but nonfossiliferous concretions occur. Similar shales occur farther northward along the old stage road from Fairview to beyond Dora, a distance of about 11 miles, and near Abinethy's they contain *Trochita filosa* Gabb and fragment of bivalves referred by Dall with doubt to the Eocene. They dip to the northeastward at an angle of 25°, and appear to plunge beneath the great irregular synclinal mass of sandstone which forms in this latitude the main body of the Coast Range.

SANDSTONES.

The sandstone which prevails in the upper portion of the series of beds belonging to the Eocene is best exposed in the prominent mountain escarpment 12 miles directly west of Roseburg. Pl. VII shows the escarpment in the distance.

At this point, as shown in fig. 4, the sandstone near its middle has a thin parting of shale which contains vegetal fragments.

It is the same sandstone which forms the crest from Tyee Mountain to Camas and apparently passes through the divide (Camas Mountain) between Olalla Creek and the Middle Fork of the Coquille to Table Mountain near Nichols Station. At Table Mountain nearly 2,000 feet of approximately horizontal sandstone are exposed, and near the summit it contains fossils which occur in the Eocene. The same is true of

VIEW WEST FROM ROSEBURG.

the east slope of Camas Mountain, where in sandstone overlying the shale a few other apparently Eocene forms were found. The fossils in this sandstone, however, are not so characteristically Eocene as are those of the shale at Bushnell's mine and near Dickinson's Rock, in the the same neighborhood.

From the bold front stretching from Tyee Mountain to Camas the sandstone extends westward toward the ocean and forms the mass of the Coast Range. It is well exposed along the old stage road from Roseburg to Coos Bay, in the canyon cut by the East Fork of the Coquille, and on the new stage road in the canyon of the Middle Fork of the same river, for nearly 20 miles west of Camas Prairie. It contains fossils 2 miles northwest of Remote, at Elbow Hill, and opposite the mouth of Boulder Creek. Fragments of Tapes, Natica, Ostrea, Tellina, Solen, Venus, Mactra, and Arca are reported by Dall, but no positive determination of species or of age is given. The dip of the beds is such as to indicate that the mountain is in part at least a syncline. This is true also on the old stage road, but not so evident, for the western limb has a very gentle inclination to the eastward, and near the middle of the mass the strata are occasionally disturbed as if faulted. The strike varies greatly, and is evidently much influenced by the proximity to the old rocks of the Klamath Mountains, which begin with the drainage of Rogue River.

The relation of this sandstone to the underlying Eocene shales is not yet definitely known. While at some points there appears to be no reason to suspect that they are discordant, at others, as for example on the Umpqua, at the base of Tyee Mountain, and near the Nineteen Mile House on the old stage road from Roseburg to Coos Bay, there is a decided unconformity suggested. It is not known, however, that the underlying strata are in all cases of the same age.

To the northward the extent of the sandstone beyond Comstock is not known. It appears to grow thinner in that direction, and possibly passes locally into shales. In the Upper Nehalem coal field, however, there is much sandstone which may belong in the upper part of this series, although it is by no means even more than probable that it corresponds closely to the heavy mass in Douglas County. In the collections from near the coal beds of Pebble Creek, *Nucula truncata* Gabb, *Tellina hoffmaniana* Gabb (?), *Tellina longa* Gabb, *Mactra ashburneri* Gabb (?), *Nererita globosa* Gabb, and *Rimella simplex* Gabb were recognized by Dall and referred to the Eocene.

Much of the Eocene sediment was derived from the Klamath Mountains and their northeast extension toward the Blue Mountains. Near their source the sediments are much thicker and coarser. Conglomerates are not uncommon in the Eocene of Douglas County, but they are rare in Columbia County. Sandstones form prominent ridges throughout the areas of Eocene west of Roseburg and about Oakland, but farther northward they make but little impression on the topography.

OLIGOCENE.

The next system of strata younger than the Eocene recognized by Dall on the Pacific Coast is the Oligocene, which includes the Astoria beds on the Oregon shore of the Columbia near its mouth.

Prof. James D. Dana,[1] in 1841, examined the shales and sandstone on the Columbia about its mouth and described them, noting also the interesting sandstone dikes which they contained. He referred to the dikes as evidence that the shales were overlain by sandstone such as that filling the fissures.

Prof. Thomas Condon collected numerous fossils at Astoria and other points in the Coast Range, and named the argillaceous shales—which he considered as forming the backbone of the range—the Astoria shales.[2]

Dr. C. A. White[3] considered part of the fossils collected about Astoria by Dana and Townsend and described by Conrad[4] as Eocene, and thus the Astoria shale of Condon was shown to embrace beds of different ages.

Dr. W. H. Dall visited Oregon in 1890, and in describing his results used the term Aturia bed for the lower or Eocene portion of the series, characterized chiefly by the presence of *Aturia ziczac*. Recognizing both the sandstone and shales referred to by Dana, he remarks:[5]

> The impression produced on the mind by an inspection of these rocks, though without the opportunity to examine any large district with care, was that the shales and sandstones form a part of a single series varying in character of its beds or layers according to fluctuations in the sedimentation, the shales being more argillaceous, the sandstones more arenaceous, neither possessing an exclusive character, the fossils appearing to be the same Miocene species in both, with a tendency to form concretions around them in the shale and to be represented by casts in the sandstones. The name of Astoria group is proposed to include them both, but not the subjacent Eocene Aturia bed.
>
> At Smiths Point, west of the town, the shales are very low, the vertical face not exceeding 15 feet. They dip about 16° in a southeasterly direction, and are composed of thin layers of chiefly bluish gray shale with numerous fractures lined with peroxide of iron, which develop more numerously as the surface dries, while the iron causes the face to weather of a brownish color. The layers mostly contain a little sand; some do not show any. The fluctuations appear to succeed each other with a certain regularity. Here and there a little gravel is mixed in one of the layers, and in these gravelly layers are also small fragments of bivalve shells, the most perfect and numerous being those of a small concentrically undulated Pecten of the section Pseudamusium; Acila and Waldheimia were also observed.
>
> In the upper layers of the shale the clayey parts occasionally form lines of concretions along a bedding plane, partly fossiliferous. The most common fossil here is a species of Macoma.
>
> Above the shales at this point is a bed of 8 to 20 feet in thickness of a yellowish clayey sand with irregular, mostly rounded fragments of a harder sandstone, macu-

[1] Wilkes Exploring Expedition, Vol. X, Geology, by Dana, p. 653.

[2] American Naturalist, June, 1880, Vol. XIV, p. 457.

[3] Bull. U. S. Geol. Survey No. 51, pp. 31–32.

[4] Wilkes Exploring Expedition, Vol. X, pp. 722–729, and Am. Jour. Sci., 2d series, Vol. V, pp. 432–433.

[5] Bull. U. S. Geol. Survey No. 84, p. 224.

lated with peroxide of iron with a few traces of marine fossils, and more or less gravel not regularly bedded, and penetrating into fissures in the shaly rock below in the form of dikes.

The Aturia bed is characterized by the presence of the form whose name it bears. It was once exposed on the water's edge at Astoria, but is no longer accessible on account of improvements of the water front. On the opposite shore of the river, three-fourths of a mile above the Knappton sawmill, the shales in which it occurs are well exposed. Aturia has been found in the shales and sandstones at a number of points south of the Columbia on both sides of the Coast Range; on the east at the fording of the Nehalem above Mishawaka, in Clatsop County, and near Blodgett in Benton County, and on the west at the old jetty quarry on Tillamook Bay.

Other fossils, relegated by Dr. Dall to the Oligocene and belonging essentially to the same horizon as the Aturia, have been found in sandstones and shales on the Scappoose, Clatskanie, and Nehalem in Columbia County, at Short Beach in Clatsop County, and northeast of Dallas in Polk County. Beginning at the north and proceeding southward, the localities will be noted first on the eastern side of the Coast Range and then on the western.

Near the sawmill at Knappton are shales with many calcareous nodules, but the only fossils found in them were fragments of crabs. Near by are exposures of old rocks upon which the shales at a number of points along the north shore of the Columbia appear to rest with a decided unconformity. At this point the older rocks strike N. 26° E., and dip 45° to 48° SE., and contain veins of calcite and possibly of quartz. Continuing along the shore, the shales appear again with approximately the same position as that noted for the older rocks. Concretions are abundant and fossiliferous, furnishing, according to Dall, the following species: *Aturia angustata* Conr., *Dolium petrosum*, *Dentalium* sp., Yoldia indet., Anatina fragment, Amusium fragment, Crabs 2 sp.

How far the Aturia-bearing shales extend eastward was not determined, although shales were exposed some distance toward Grays Bay, beyond where the fossils were obtained. There must be at least 500 feet of shales exposed at this point.

On the road to Mist, 2 miles southwest of Clatskanie, at an elevation of about 150 feet above the river, there is a mass of soft sandstone containing a very fossiliferous nodule 2 feet thick. *Dolium petrosum* Conr., *Nererita globosa* Gabb, *Nucula truncata* Gabb, Callista, and Diplodonta are among the forms recognized by Dall. The position of the strata is not readily determined with certainty, but there are indications that they dip northerly. If so it would be expected that the soft sandstone containing the nodule would be younger than the shaly sandstones on the same road at an elevation of 700 feet. This is not true, however, for the fossils the latter contain are Pliocene.

Several years ago, through Mr. Will Q. Brown, a small collection of fossils was obtained from Westport on the Columbia. Dr. Dall reported (letter December, 14, 1892) that they belong "probably to the horizon of the Aturia bed which immediately underlies the Miocene Astoria shales."

On the North Fork of the Scappoose, about 5 miles northwest of the station of the same name at the mouth of Fall Creek, the soft, gray, fine sandstone is cut to small pieces by joints, yet some of the fossils are well preserved, and among them Dr. Dall identified *Nucula truncata* Gabb, *Fusoficula tricarinata* Lam., and *Nererita aëtites* Conr. (?), besides a number of other forms. The position of the beds is strike N. 40° W., dip 19° to the southwest.

About 20 miles northwest of Scappoose, at Pittsburg, on the Nehalem, is one of the finest exposures of Oligocene strata observed in Columbia County. A view of the bluff is given in Pl. VIII. The upper soft gray sandstone is very fossiliferous in places, and about 30 feet in thickness. Below are 20 feet of dark shales which weather gray. The whole series dips northeast at an angle of about 5°. Some of the layers of sand are indurated so as to make slabs, thickly set with perfectly preserved fossils. Generally the sandstone is soft and the numerous fossils it contains are so fragile as to be preserved with great difficulty. Solen is abundant in one or more of the layers, and recalls the name Solen beds, proposed by Condon[1] for the sandstones overlying the Astoria shales of the Coast Range generally. Among the grains of sand in the sandstone are found particles of pumice, probably indicating contemporaneous volcanic activity.

The fossils identified by Dr. Dall from this locality are *Nucula truncata*, *Solen parallelus* Gabb, *Mya præcisa* Gld., *Nererita saxea* (?) Conr., besides Leda, Dentalium, Diplodonta, Macoma, Tellina, Callista, Mactra, Lunatia, Cylichna, and Molophorus, of which most of the species are new.

The fossils of the shales are generally contained in concretions, some of which are large. Farther up the Nehalem, 1 mile beyond Vernonia, the same dark shales, weathering gray, occur as at Pittsburg. Thirty feet of them are exposed by the stream, and they are nearly horizontal. When wet and dried in the sun they fall to pieces, so that erosion is rapid. Fossils are not uncommon. All those collected here were found also at Pittsburg excepting Pentacrinus and Periptoma.

At Wilsons Bluff on the river, 3 miles above Vernonia, gray shales appear, with concretions, some of which are 10 feet in diameter, parallel to the bedding and 2 feet perpendicular to it. Most of the concretions are small, and, as already noted at many other places, contain the carapace or legs of crabs. The strata dip gently to the eastward, and it is evident that the shales above Vernonia are older than those at Pittsburg. Although the whole section seen on the Nehalem from Wilsons Bluff to Pittsburg is at least 10 miles in length, it is not directly across

[1] Am. Naturalist, June, 1890, Vol. XIV, p. 457.

PITTSBURG BLUFFS.

the strike and does not expose more than a few hundred feet of shales and overlying sandstone.

The fossils found at Wilsons Bluff are *Dolium petrosum* Conr., *Nucula truncata* Gabb, *Yoldia impressa* Conr., *Pseudomusium peckhami* Gabb, with Dentalium, Scaphander, Cylichna, Leda, and Tellina. The party did not follow the Nehalem farther up than Wilsons Bluff, but the section must be quite like that of Rock Creek, a short distance to the northwest, where the Oligocene shales are covered by Pliocene tuffs and are succeeded westward by Eocene shales and underlying volcanics. The southern part of Columbia County, taken in connection with the adjoining portion of Washington County, probably affords the best ground in the State for studying the relations of the Eocene, Oligocene, and Miocene.

Extending south from Vernonia, the Oligocene soon passes under the Miocene, which forms the divide in that direction, and was not seen again along the eastern foot of the coast range until Polk County was reached. Very likely it crops out at many points along the range, especially along the higher portions of Gales Creek and Tualitin, for it appears again 8 miles northeast of Dallas, on the divide between McCoy and Derry, where 50 feet of sandstones with thin beds of gray shales are overlain by 40 feet of light-colored shales from the soft, crumbly sandstone, dipping 10° to the northeast. Numerous fossils were obtained. Of these only *Tritonium californicum* Gabb, *Trochita filosa* Gabb, *Cuma biplicata* Gabb, and *Clavella gravida* Gabb (?) were specifically identified, although eight other genera were represented. They were referred by Dr. Dall with doubt to the Oligocene. But this may well be correct, for the position of the strata shows that they lie beneath the Mioeene strata seen to the northward and overlying the Eocene in the opposite direction. In the overlying light-colored shales no fossils were found. They look somewhat like the Miocene shales of Washington and Columbia counties, but so far as yet seen do not contain evident radiolarian or volcanic fragments.

The most southern outcrop of strata referred to the Oligocene is in Blodgett Valley, about a dozen miles west of Corvalis, on the road to Yaquina Bay. The shales and thin-bedded sandstones contain much volcanic material. They dip 40° to the northwest, and in a bluff north of the road 50 feet of them are well exposed. Half a mile northeast of Blodgett Station Mr. Anderson discovered in these tuffaceous beds fragments of *Aturia angustata*, with Ostrea, Peeten, Cardium, and Leda, which Dr. Dall referred with doubt to the Oligocene.

Turning now to the western slope of the Coast Range, the first locality of Oligocene south of Astoria is noted at Short Beach, in Clatsop County, where about 250 feet of thin sandstones and shales are exposed between projecting points of igneous roeks. Near the middle of the beach the upper beds of dark shale contain concretions in which were found *Dolium petrosum*, *Rostellites indurata* Conr., Arca, Macoma, Dentalium, and fish bones, indicating approximately the same age as the very lowest beds at Astoria and at Knappton, across the river. The only fossils found in the sandstones and shales on the coast between Astoria and Short Beach are Miocene. Directly eastward, about 6 miles from Short Beach, the Miocene occurs, near Crawford, and twice as far to the southeast is the Eocene, at Felix Roy's, on the Nehalem.

To the southward on Tillamook Bay at several points rocks are well exposed, and they are at least in part fossiliferous. At the entrance of the bay on the north side the ledges of sandstone and conglomerate dip southwest, with a southeast strike, carrying the beds across the bay toward the jetty quarries, where they are fossiliferous. The conglomerate occasionally contains pebbles 4 to 6 inches in diameter, and beneath the conglomerate and sandstones lie shales which, at Garibaldi, are hard and slaty; but this induration may, perhaps, be attributed to the eruptive rock near by. On the eastern shore of the bay, nearly midway between Hopkinsville and Bay City, are shales with concretions containing Dentalium and fish bones, and these shales are overlain by sandstones dipping gently to the southwest. Judging from the position of the strata exposed on the eastern side of the bay, they underlie those of the point northwest of Garibaldi and in the bluffs along which the jetty quarries occur.

Along the southwestern shore of the bay, from the mouth of the Tillamook River to the Spit, is a prominent bluff of soft, gray sandstone, from which the stones for the jetty have been obtained. At the southeastern end, in the old jetty quarry, about 80 feet are exposed, and it contains shells and casts throughout, although they are most abundant in the concretions, which are usually less than a foot in diameter. The strata dip gently to the southwest, as at other points on the shore of the bay, and strike more northerly than the face of the bluff, which, considering its whole length of nearly 3 miles, exposes several hundred feet of strata, almost wholly gray sandstones, generally so soft as to be readily crushed in the hand. When the fossils were collected in the old jetty quarry Mr. Anderson recognized the occurrence of Aturia[1] with Miocene forms, and it was considered evidence that Aturia survived into the Miocene. The determination of these fossils from the old jetty quarry by Dr. Dall proves of much interest. He finds the Oligocene forms *Aturia angustata* Conr., *Dolium petrosum* Conr., *Rimella simplex* Gabb, as well as the Miocene forms *Pecten propatulus* Conr., *Pyrula pyriformis* Gabb (?), *Crepidula prærupta* Conr., *Lunatia* sp., *Bulla petrosa* Conr. (?), *Arca microdonta*, *Thracia trapezoides* Conr., *Venericardia subtenta* Conr., *Cryptodon bisectus* Conr., *Macoma arctata* Conr. (?), *Tapes staleyi* Gabb (?), besides species of Yoldia, Leda, Chione, and Modiolaria. In the field the strata were supposed to be Miocene, but it was not noted whether both Oligocene and Miocene fossils occurred in the same nodule. If they occur in different nodules it might be said that the Oligocene nodules were derived by erosion from

[1] According to Dall (Bull. U. S. Geol. Survey No. 84, p. 223), Professor Condon obtained an *Aturia ziczac* at Tillamook.

strata of that age and deposited with the Miocene fossils where we now find them together. There was nothing whatever observed at the time the fossils were collected to suggest that they had not all lived together at the time the strata in which they occur were deposited. It is certain that Dolium continued into the Miocene, for it occurs in the Empire beds at Coos Bay. Although this exposure is described under the Oligocene, the predominance of Miocene forms would appear to show that it belongs rather to the Miocene.

On the western slope of the Coast Range south of Tillamook Bay no Oligocene was observed, although it may well be there. At Coos Bay, where the Miocene (Empire beds) comes in contact with the Eocene (Arago beds), it was not observed.

MIOCENE.

The Miocene is widely distributed in western Oregon upon both sides of the Coast Range. It occurs over a large part of the Willamette Valley, especially in Washington, Yamhill, and Lane counties, and on the coast more or less continuously from Astoria to Coos Bay, and most likely beyond, with interruptions, to California.

Beginning at Astoria, the localities will be noted in order from north to south, first upon the eastern side of the range and then upon the western.

The Miocene of the Astoria region recognized by Dana consisted essentially of two members—sandstone above and shales below. By White and Dall the lower portion of the shales was shown to be older than the Miocene, but above the Aturia bed there was still recognized a mass of shale to which Condon's term Astoria shale was applied. Although Dall[1] at one time considered these shales as Miocene, he has since placed them under the Oligocene in his correlative tables.[2]

The age of the shales may yet be a matter of considerable doubt, but the overlying sandstone is without question referred to the Miocene. The upper part of the shales, where the thin, sandy layers begin to predominate, is shown in Pl. IX, from a photograph taken near the High School building in Astoria. They are cut by a small sandstone dike. For many years after Dana's visit to that region sandstone dikes were well exposed in Astoria and along the shore toward Tongue Point. They closely resemble those of Tehama County, Cal.,[3] where they have been shown to be earthquake fissures filled with sand from below. Dana regarded those at Astoria as fissures filled from above, and used the dikes as an argument to show the relative position of the sandstone and shale.

South of Astoria, on the eastern side of the Coast Range, the first Miocene strata observed were on the Nehalem, near Mist, in Columbia County. In the river the shales strike N. 22° W., and dip 13° to the

[1] Bull. U. S. Geol. Survey No. 84, pp. 223-226.

[2] Seventeenth Ann. Rept. U. S. Geol. Survey, Part III.

[3] Bull. Geol. Soc. Am., Vol. I, p. 411.

southwest, so that ascending the river we appear to descend the series of rocks. A little farther up the river prominent bluffs of shale appear on the left bank. One hundred feet of whitish material consists chiefly of radiolarian fragments with some particles of pumice. This bed, as illustrated in fig. 6, overlies fossiliferous shale, of which only 10 feet are exposed. The strata are considerably faulted and crushed, and the fossils distorted. Dr. Dall recognized *Yoldia impressa* Conr., *Yoldia* n. sp., *Leda* n. sp., *Nucula divaricata* Conr., *Nucula truncata* Gabb, Dentalium two n. sp., and Lunatia sp., which he referred with some doubt to the Miocene.

The shales are cut by several sandstone dikes. The largest is very irregular, and ranges from 1 inch to 2 feet in thickness, and branches upward. It is composed of sand which is made up chiefly of volcanic material.

From Mist the river flows northwest for several miles and then turns southwest to cut across the Coast Range. There are few exposures by the road in that direction until Jewell is reached, where Oligocene or Eocene shale occurs.

Four miles up the river from Mist, near the mouth of Battle Creek, is a prominent bluff of fossiliferous sandstone. The strata are practically horizontal and associated with a small exposure of basalt. Among the fossils Dr. Dall reports *Mactra albaria* Conr., *Yoldia cooperi* Gabb, with Tellina, Solen, Macoma, Fusus, and Natica, which he refers to the Upper Miocene.

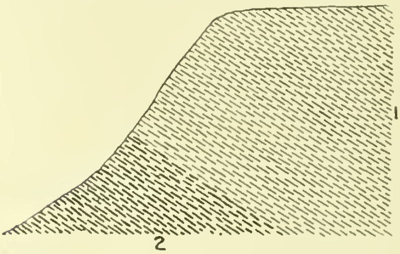


FIG. 6.—Section of left bank of Nehalem River, near Mist. 1, Whitish, tuffaceous radiolarian shale; 2, Fossiliferous dark shale.

On the East Fork of the Nehalem, about 6 miles southeast of Pittsburg, and belonging apparently to a higher horizon than the sandstone and shales of that place, is a soft, yellowish sandstone associated with a bed of coal 4 to 6 feet in thickness. Among the few fossils found there are *Callista angustifrons* Conr., *Mactra albaria* Conr., and others which Dr. Dall refers doubtfully to the Miocene. These fossils are quite unlike those (Eocene) associated with the coal on Pebble Creek, and indicate that the coal of the two localities does not belong to the same bed.

The divide between the Nehalem River and Dairy Creek, especially the southern slope, is composed of Miocene strata. The lower strata appearing to the westward are chiefly shales, while the upper ones are for the most part sandstones.

On Gales Creek, a mile above the post-office, over 100 feet of dark shales, dipping 40° to the southeast, are exposed in the bed of the stream, and a short distance farther down contain Mytilus, Macoma, Lyonsia, and Yoldia. The species are all new, but are regarded by Dr. Dall as probably Miocene.

ASTORIA SHALES AND SANDSTONE DIKE.

On the West Fork of Dairy Creek both sandstones and shales occur. The latter are dark within, but weather gray, and when freshly broken have a decided odor of petroleum. The best exposure is in sec. 32, T. 3 N., R. 4 W., where a large landslide has occurred, exposing 250 feet of the shale. It is rather massive than fissile, and contains, besides occasional casts of mollusks, numerous small fragments of carbonized vegetal matter and minute bright scales of muscovite. Under the microscope it is seen to contain some volcanic material, also traces of radiolaria, and occasional green grains of glauconite. The fossils found here, *Yoldia impressa* Conr., *Callista angustifrons*, *Lucina acutilineata* Conr., with others not specifically determinable, are referred to the Miocene. The occurrence of bituminous light-colored shales in Oregon containing radiolarian and volcanic fragments is of much interest on account of their close resemblance to the Monterey shales of California. By the kindness of Prof. A. C. Lawson, of the State University of California, who sent me a number of samples of the Monterey shales, I am able to compare them. Although those of Oregon are generally not so light colored, they are occasionally almost as white as chalk. Generally, however, there is no trace of bituminous matter about them, at least so far as one may judge from surface indications.

On the West Fork of Dairy Creek these shales dip gently eastward, beneath the soft sandstones exposed lower down on the same stream. On the East Fork of Dairy Creek the sandstone is approximately horizontal, and occasionally very fossiliferous. A coulée of basalt cascades over the side of the canyon 4 miles above Mountain Dale. A collection of fossils was obtained at this point, and Dr. Dall recognized *Nucula divaricata* Conr., *Yoldia cooperii* Gabb, *Mactra albaria* Conr., *Mya præcisa* Gld., *Crepidula prærupta* Conr., and other forms, which he regarded as indicating a horizon well up in the Miocene.

The same group of strata extends northeast to the Scappoose, where, in section 34, by the kindness of Dr. David Raffety, specimens of *Mactra albaria* Conr. and other forms were obtained. A short distance farther up the same stream, at the mouth of Fall Creek, the Oligocene occurs.

Southward from Forest Grove an excellent exposure of dark-gray fossiliferous Miocene sandstone occurs at Boos's quarry, near Dilley. At least 100 feet of sandstone is exposed, dipping to the northeast at an angle of from 34° to 41°. Fossils are abundant, and evidently Miocene. On the Scoggins Creek road, a short distance above the road to Boos's quarry, a series of fossiliferous strata occur in essentially the same position as those at the quarry.

At the south end of Wapato Lake, on the road crossing to the base of Chehalem, there are shales which stand out in the valley farther from the foothills of the Coast Range than the two localities last mentioned. In the calcareous nodules of the shales *Pseudamusium peckhami* (?) Gabb and other Miocene forms were obtained. A prominent hill called Chehalem is capped by basalt. Although Chehalem Valley is remarkable for its fertility and rural beauty, it affords few exposures of rocks except those of basalt upon the hills. After leaving Wapato no Miocene was encountered until near the southern border of Benton County.

A few years ago Mr. John Ray sent to the National Museum fossils from Foster's ranch, about 12 miles southwest of Corvallis, and they were referred by Dr. Dall to the Miocene. It is probable that they were collected to the east of the locality from which the Eocene fossils previously mentioned were obtained.

In the gray sandstone quarry on the road within a quarter of a mile west of Monroe a few fossils were found, among which Dr. Dall recognized *Crisotrema condoni* Dall, *Mactra albaria* Gabb, with Trochita, Crepidula, Fusus, Crassatellites, and Dentalium, and referred them to the Miocene. The sandstone dips gently toward the Willamette only a few miles to the eastward, and is probably continuous with similar beds near Eugene, where numerous characteristic fossils have been found by Condon and Dall.[1]

It is generally believed that the Miocene east of the Coast Range does not extend farther south than to the head of the Willamette Valley, but a suggestion has recently been found in some fossils collected near Oakland that it extends into Douglas County. In the calcareous shales near the forks of the road one-half mile east of Oakland, *Lucina acutilineata* Conr. was obtained. Dr. Dall informs me that it is known only in the Miocene, and is believed to be characteristic. The number of fossils, however, is small, and they occur in a region apparently surrounded by Eocene, so that their presence can scarcely be regarded as more than a suggestion.

Upon the western side of the Coast Range, south of Astoria, the first strata supposed to be Miocene were observed at Tillamook Head, where Professor Dana[2] reported a cliff of light and dark blue clay 900 feet in height.

At the northern end of the head, near Seaside, light-colored shales with occasional concretions occur. No large fossils were seen, but the radiolarian tuff is quite like that which occurs at Mist and elsewhere in the Miocene shales, so that there can be little doubt as to its position. Farther along, the strata are somewhat more sandy, and are succeeded by cliffs of basalt, rendering the shore impassable for a number of miles.

Near Seaside the road leaves the beach and crosses Tillamook Head to Cannon Beach. Outcrops of both shale and basalt occur by the way. At the southern side of Tillamook Head the sedimentary rocks appearing with the eruptives are thin-bedded. The sandstones, ranging in thickness from 5 to 18 inches, are separated by thin shales. The eruptives contain many veins and nodules of calcite, and some of quartz.

Below the mouth of Elk Creek, along Cannon Beach, are fine exposures of conglomerate, sandstone, and shales over 60 feet in thickness,

[1] Bull. U. S. Geol. Survey No. 84, p. 227.
[2] Wilkes Exploring Expedition, Vol. X, Geology, by Dana, p. 653.

cut by irregular dikes of basalt. The sedimentary rocks are soft, like the Merced series of Lawson on the coast near San Francisco. But the few fossils they contain near Haystack Rock—Nucula, Leda, and Tellina—are not specifically identifiable, and Dr. Dall relegated them with doubt to the Miocene. Shales are most abundant. They strike N. 13° W., and dip 23° to the northeast, but the position is variable. Normal faults are common, and trend nearly parallel to the strike of the strata, with the downthrow to the northward. Nearing Mrs. Austin's, at Cannon Beach post-office, sandstones with beds of pebbles form prominent outcrops, in which the waves have carved caverns.

Cannon Beach is about 9 miles in length, and is limited to the south by Arch Cape, composed of basalt, which is in part overlain by soft, yellowish sandstone. Short Beach, which lies on the south, next to False Tillamook, exposes a series of Oligocene strata, and Neahkahnie Mountain beyond, of igneous rocks, forms a bold promontory.

No fossils were found in immediate connection with the coal in the Lower Nehalem basin, but at Crawford's, on the North Fork, about 6 miles above the post-office of Nehalem, there are soft shales, locally calcareous and much crushed, containing a few forms. The fossils are contained in the calcareous layers and nodules, and among them Dr. Dall identified *Mactra albaria* Conr., *Yoldia impressa* Conr., *Arca obispoana* Conr., *Pecten propatulus*, and *Trochita filosa*, which he refers to the Miocene.

A few miles southeast of Crawford's the volcanic Eocene occurs on the Nehalem at Felix Roy's, but down the coast the Miocene was not recognized again until Tillamook Bay was reached. In the heavy mass of sandstone at this point there is such a mixing of characteristic Oligocene and Miocene species that the age of the beds is a matter of doubt. Although it is believed that they are essentially Miocene, they were described and the fossils noted under Oligocene.

The shore between Tillamook Bay and Oyster Bay is a line of bold basalt bluffs, but occasional masses of sandstone are included in the eruptives, as may be seen on the beach south of Meares Point light. Between Meares Point and Otter Rock, near Yaquina Bay, there have been few if any geological observations on the coast, and the character of the exposed rocks is not known. The occurrence of several prominent heads suggests the presence of eruptives that locally interrupt the continuity of the sandstones.

In the region of the Yaquina Bay, extending north beyond Otter Rock, the Miocene has its greatest development on the coast of Oregon and is well characterized by an abundance of fossils. A general view at this point is illustrated in Pl. X. The strike of the strata about Otter Rock varies from N. 8° to 13° W., with a westerly dip at an angle of about 18°. The abrupt change of sediments at the southern end of the rock, where the road ascends to the top of the terrace and the small exposure of the light-colored Miocene beds is greatly fractured, suggests displacement of the strata. This suggestion is emphasized by the small faults well exposed on the north side of Otter Rock. That no great displacement occurs, however, is clearly indicated by the fact that the thin-bedded yellowish sandstone of which Otter Rock is composed contains a few miocene fossils, which relate it quite closely to the fossiliferous beds a short distance on both sides.

South of Otter Rock to the point at Newport, and along the bay to the town of Yaquina, the rocks are chiefly shales, generally fossiliferous, and dipping toward the sea. At Yaquina calcareous concretions are abundant and full of fossils. In the collections between Yaquina and Otter Rock, along the coast, Dr. Dall identified the following forms:

1. Otter Rock and along the beach 1 mile northward:

Margarita striata Brod., and the common Arca, Natica, and Callista, Mactra albaria Conr.

2. On the beach from Otter Rock south to Cape Foulweather:

Pecten propatulus Conr.
Tellina arctata Conr.
Panopea abrupta Conr.
Callista angustifrons Conr.
Arca microdonta Conr.
Nucula conradi Week.
Sigaretus scopulosus Conr.
Pyrula modesta Conr.
Crepidula prærupta Conr.
Large Pleurotoma and Buccinum.

3. Nye Beach to Cape Foulweather:

Crepidula prærupta Conr.
Euthria like dira Roe.
Purpura n. sp. (?)
Natica sp.
Leda like cœlata Hinds.
Yoldia sp.
Arca microdonta Conr.
Arca inezana Conr.

4. North beach of Yaquina Bay:

Nucula truncata Gabb.
Lucina acutilineata Conr.
Natica sp. undet.

5. East shore of Yaquina Bay:

Mytilus (large).
Macoma.
Callista.
Lutricola unda Conr. (?)
Lucina.
Callicardia. (?)
Cardium.
Mya præcisa Gold.
Arca microdonta Conr.
Yoldia impressa Conr.
Dentalium n. sp.
Trochita filosa Gabb.
Pleurotoma like circinata Dall.
Buccinum like plecteum Stm.

Shaly sandstones begin near Yaquina, and according to Mr. Anderson they are succeeded by massive beds to the eastward, along the Yaquina River. In a railroad cut at Rocky Point, 4 miles east of the town, dark shales appear and contain many calcareous concretions, in which the following fossils were found:

Nucula conradi Week.
Modiola sp.
Tellina arctata Conr.
Macoma sp.
Callista angustifrons Conr.
Cardium modestum Ad. and Roe.
Lucina acutilineata Conr.
Crepidula prærupta Conr.
Dolium petrosum Conr.

VIEW LOOKING NORTH ALONG NYE BEACH TO CAPE FOULWEATHER.

It appears that the sandstone just referred to lies beneath the shales of the coast and overlies those of Rocky Point. This sandstone, so far as can be judged from what is already known of its position, is possibly the one exposed in the Yaquina coal field west of Depot Slough, where in Jones Tunnel fragments of Mytilus, Macoma, Mactra, Yoldia, Dentalium, and Natica were found, and referred by Dall, with doubt, to the Miocene.

To the eastward of Toledo there are a few outcrops before reaching Pioneer, where massive sandstone is well exposed and extensively quarried. It is gray and rather soft, so as to be easily removed and carved. The thickest blocks obtainable are about 10 feet. Other layers range as low as 4 feet, and they are separated by films of clay.

Near Pioneer the sandstones strike east and west, with a dip of 20° to the northward. Beyond Pioneer shales become more prominent again, intermingled with soft sandstones, and continue toward the summit. No fossils were found east of Pioneer. The incoherent character of the beds and their gentle inclination (with few exceptions much disturbed) suggest that they may be younger than the upturned fossiliferous strata of the coast. Elevated beaches are occasionally well marked, and it appears that at no very remote epoch, geologically, the sea may have passed through the low gap into the Willamette Valley. The soft sandstones and shales continue east of the summit to near Blodgett Valley, where they are replaced by beds of volcanic material and old lavas like those seen on the Nehalem.

The strike of the Miocene rocks at Yaquina carried them down the coast, and their occurrence with an abundance of fossils at Coos Bay indicates that they are continuous between these two points. The Miocene rocks of Coos Bay are well exposed on the beach 3 miles southwest of Empire City, between Pigeon Point and Fossil Point. They are so well characterized at this locality by their fossil contents and position with reference to the adjoining rocks that we designate them the "Empire beds." These beds are more sandy than at Yaquina, and contain numerous fossils. On the wave-cut terrace they appear to be horizontal, but structural lines show here and there, indicating that the strike varies from N. 7° to 10° W., and the dip from 7° to 11° SW. Concretions are common and contain most of the fossils, but *Pecten propatulus* and some other forms are scattered throughout the Empire beds. From the collections made Dr. Dall reports:

Crepidula prærupta Conr.	Pecten propatulus Conr.
Dolium petrosum Conr.	Callista angustifrons Conr.
Lunatia sp.	Mactra albaria Conr.
Pectunculus patulus Conr.	Cryptoda bisectus Conr.
Yoldia near lanceolata Sby.	Thracia trapezoides Conr.

The distance from one point to the other along the shore is only about three-eighths of a mile, and owing to the gentle dip of the strata less than 300 feet (estimated) are exposed. The Empire beds may be seen for some distance along the east shore of South Slough and along the mouth of the bay from South Slough toward Cape Arago as far as Coos Head. In the bluff east of Coos Head the massive Miocene sandstone containing occasional valves of *Pecten propatulus* strikes N. 25° W. and dips 18° to the northeast. This massive sandstone, with its gentle dip, extends westward along the shore from Coos Head only a short distance, for before reaching Tunnel Point the highly inclined Arago beds (Eocene) form the bluff. The Empire beds and the Arago beds meet between Tunnel Point and Coos Head, and there is every indication that they are markedly unconformable.

At Fossil Point occurs the most remarkable fossiliferous rock seen anywhere on the coast. Owing to the very large number of perfect fossil shells it contains, it is locally known as Fossil Rock. It is of small extent, and rests directly and unconformably upon an eroded surface of the Empire beds. The contact is plainly visible. It is evident, therefore, that the Empire beds are not only well characterized by fossils, but are limited both above and below by unconformities.

It is probable that the Empire beds extend some distance toward the Coquille, for on the beach at the mouth of Twomile Creek were found a number of Miocene fossils brought down by that stream, and according to Newbury[1] and Condon, a narrow strip of arenaceous Miocene rocks extends more or less continuously from Cape Blanco to Port Orford.

PLIOCENE.

Of the many lots of fossils collected during this reconnaissance in northwestern Oregon, only two have been definitely referred by Dr. Dall to the Pliocene. Both were obtained in Columbia County, one from Rock Creek, about 4 miles above Vernonia, and the other from the north slope of the mountain by the western road from Clatskanie to Mist, at an altitude of 700 feet above the sea.

Going up Rock Creek from Vernonia one finds shales exposed here and there along the road, overlain by a light-colored tuff which in places looks very like a sandstone, but under the microscope it is seen to be composed wholly of volcanic dust. The shales, judging from those on the Nehalem above Vernonia, are probably Oligocene, and are in unconformable contact with the tuff. The tuff forms a conspicuous bluff, which had to be excavated to allow the road to pass above the stream. In the loose fragments at the bottom of this bluff a few fossils were collected, among which Dr. Dall recognized *Yoldia cooperi* Gabb, Macoma sp., *Terrebratulina unguicula* Cpr., *Opalia ruderata* Dall n. sp., Pleurotoma n. sp., and Dentalium n. sp., and remarks that they belong to the Pliocene (horizon of Pacific Beach, San Diego, Cal.) and indicate rather deep water.

The light-colored rock of the bluff contains not only the fossils already

[1] Bull. U. S. Geol. Survey No. 84, p. 223, footnotes 1 and 2.

enumerated, which are visible to the unaided eye, but also multitudes of radiolarian fragments. Many of the latter are readily recognized by their dark honeycomb or reticulated structure, but others, derived from the spines or cellular spaces of the radiolarian skeletons, show no mark of their organic nature and look like fragments of volcanic glass. There are, however, some particles of pumice present, and in general they may be distinguished from the radiolarian spines by the bubbles of gas or inclusions of differently colored glass which they contain. The bed of radiolarian tuff is about 70 feet in thickness and nearly horizontal. Its laterial extent is not known, but it must be considerable, for the fossils it contains indicate its marine deposition in rather deep water.

The second locality of Pliocene to be noted is on the western road from Mist to Clatskanie. The summit of the divide by the road is sandstone, at an altitude of about 1,200 feet, although farther east it is capped by lava and is considerably higher. At an elevation of about 700 feet, in soft shaly sandstone, *Yoldia impressa* Conr., *Solemya ventricosa* Conr., and *Lucina acutilineata* Conr. were found, and referred to the Pliocene. Farther down upon the same slope, in a similar sandstone, numerous Oligocene fossils were obtained.

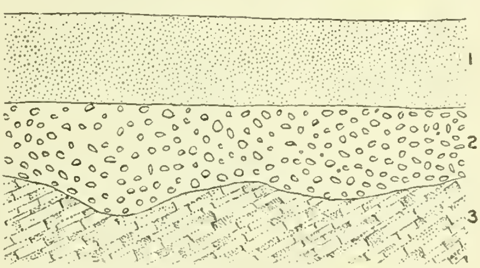


FIG. 7.—Section at Fossil Rock. 1, Sand (Pleistocene); 2, Fossil Rock (Pliocene); 3, Sandstone (Miocene).

Although Pliocene strata may be quite widely distributed in northwestern Oregon in places we did not examine, it does not appear probable, for the only other locality of marine sediments known that can be referred to the Pliocene, excepting, perhaps, the upper Miocene on the Nehalem, 4 miles above Mist, is the remarkable "Fossil Rock" on Coos Bay, $3\frac{1}{4}$ miles southwest of Empire.

This rock, well known in the community as Fossil Rock, is essentially a conglomerate. Besides a great abundance of almost perfect shells, it is composed of pebbles and angular blocks and concretions of the Miocene sandstone (Empire beds), upon which it rests unconformably, as illustrated in fig. 7. The contact of Fossil Rock and the Empire beds is clear, and there can be no question that the Empire beds were consolidated and eroded, and that thus many of their fragments and fossils were mingled with the then living forms of which Fossil Rock is composed.

The large number of shells accumulated upon the Empire beds in some of the little coves near by illustrate the way in which Fossil Rock was formed. It is important to bear in mind, however, that, as shown by Mr. Walcott[1] in considering intraformational conglomerates, it may

[1] Bull. Geol. Soc. America, Vol. V, p. 191–198.

be possible for just such material as Fossil Rock to form essentially contemporaneously with the beds of whose fragments it is composed.

The close correspondence of the fossils to those of the underlying Empire beds relegates it to the Miocene, but the apparent physical break shown by the relation of the beds indicates that it may be considerably younger than that portion of the Miocene represented by the Empire beds. It is certainly older than the Pleistocene beds by which, as seen in fig. 7, it is overlain.

In the collection from Fossil Rock Dr. Dall recognized *Chrysdomus* like *fornicatus* Gray, *Lunatia* sp., *Crepidula prærupta* Conr., *Pecten propatulus* Conr., *Tapes staminea* (Staleyi (?) Gabb), *Mactra albaria* Conr., Dione, Chione, Cardium, Macoma, and *Callista angustifrons* Conr., and referred them to the Upper Miocene, remarking, "This assembly is about like that which Merriam lists (letter of Prof. A. C. Lawson, June 18, 1895) from Coos Bay," and to which Lawson[1] referred in suggesting that the Wild-cat series (Pliocene) extends as far north as Coos Bay.

Fossil Rock is as firm as the Empire beds on which it rests, but is of limited extent, covering an area of only about 1 acre, with a thickness of less than 20 feet. Beds corresponding to Fossil Rock were not discovered anywhere else in the neighborhood, or along the coast elsewhere, unless at Hinton Point, opposite Newport, on the Yaquina Bay, where Professor Condon is of the opinion that the Pliocene occurs. The deposits at Hinton Point are noted more particularly under Pleistocene. Strata continuous with Fossil Rock would not be expected to extend inland, for it is a characteristic shore deposit.

The only other matter to be considered under the head of Pliocene is the occurrence of a mastodon tusk at Gravel Ford, on the North Fork of the Coquille, 7 miles from Myrtle Point. It was taken from the bank 9 feet above the level of the river, and is said by Mr. Orville Dodge, from whom I obtained fragments of the tusk, to have been 3 feet in length. Mr. F. A. Lucas, of the U. S. National Museum, examined the fragments and identified them as parts of the tusk of a mastodon which lived probably during the Pliocene period. The tusk had a peculiar enamel band.

From the small amount of evidence at hand concerning Pliocene geography, it seems that the Klamath Mountains, and the larger portion if not the whole of the Coast Range, were above the sea during that period. Besides the little strip at the mouth of Coos Bay, the only land of northwest Oregon now known to have been covered by the Pliocene sea lay in Columbia County, near the east base of the Coast Range. It is very probable, however, that the Willamette Valley was then filled by the sea, for, as we shall see in the sequel, Willamette Sound filled it for a portion of the next succeeding period.

[1] Bull. Univ. of California, Department of Geology, Vol. I, p. 256.

PLEISTOCENE.

Under the Pleistocene are considered all those deposits which are more recent than the Pliocene. They are not distinguished in general so much by fossils as by the unconsolidated character of the deposit and its position. They are widely distributed, and will be described in the order of their occurrence from the Columbia southward, but in this case first upon the west slope of the Coast Range and then upon the east, and in the Willamette Valley.

At Ilwaco, on the north bank of the Columbia near its mouth, is an exposure of which a sketch is shown in fig. 8. The upturned edges of the Astoria shales make the mass of the hill, and these shales are unconformably overlain about 30 feet above sea level by a series of gravel, sand, and clay layers 14 feet thick. The material in these layers is incoherent and contains occasional fresh fragments of shells belonging to species yet living on the coast. Near the middle of the deposit is a dark seam of vegetal matter, and the character of the stratification is such as to indicate that the deposit is waterlaid and not of eolian origin.

At the base of the hill the upturned edges of the shales have been cut off to an even surface by the waves, and this wave-cut terrace extends more than 100 yards toward the river. The top of the shales, in the hill immediately beneath the Pleistocene layer, is planed off in the same way, and it is evident that when this was accomplished the shale in the hilltop was then at the sea level and the waves rolled over it as they now roll over the lower wave-cut terrace to reach the beach.

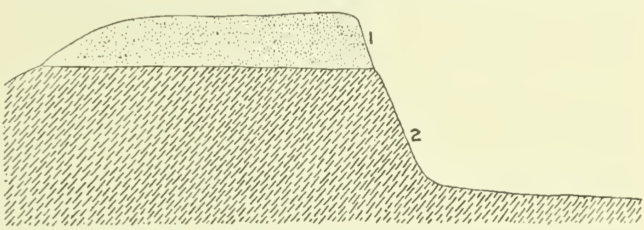


FIG. 8.—Section of shore near Ilwaco, showing a layer of Pleistocene sand (1) unconformably overlying tilted shales (2).

The Pleistocene capping of the hill was laid down when the ancient wave-cut terrace was below the sea level deep enough to receive the deposits we now find there. Since then, of course, it has been raised to its present elevation by a general, perhaps more or less unequal, uplifting of the land along the coast.

Going south from the Columbia, along the Clatsop coast, one's attention is first attracted by the remarkable series of ridges, of which more particular mention has been already made in this paper under the head of "Features of the Oregon coast." At Tillamook Head and False Tillamook there are prominent cliffs along the beach, but late deposits, corresponding to those noted at Ilwaco, although doubtless present, are not well exposed.

Below the mouth of the Nehalem, however, they appear in the sea cliff by the beach. As shown in the following section, fig. 9, the strata are horizontal, and, beginning below, consist of (*a*) bony, carbonaceous clay, 5 feet; (*b*) sand, 3 feet; (*c*) gravel, stumps, logs, etc., 5 feet; (*d*) sandy clay, 12 feet; making a total thickness of 25 feet. A small stream reaches the beach by a little gulch cut through a 25-foot bluff containing these strata. The stream has cut down to the bony, carbonaceous layer, and from the top of that layer it falls to the beach. The stream is so small that it works slowly, and has failed to cut down to sea level, as have the larger streams. Such a fall in a large stream might be taken to indicate a very recent uplift along the coast at that point.

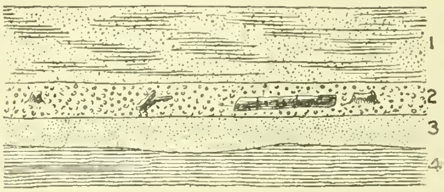


FIG. 9.—Section of sea cliff below the mouth of the Nehalem. 1, Sand and clay, 12 ft.; 2, Gravel, stumps, logs, etc., 5 ft.; 3, Sand, 1–3 ft.; 4, Carbonaceous clay, 5 ft.

South of Tillamook Bay is a prominent bluff where the Meares Point light-house is located. Near by is a bluff of basalt, estimated to be about 300 feet in height, capped by 20 feet of soft sandstone, which belongs to the series of comparatively incoherent Pleistocene deposits. This was not examined close at hand, but the stratification appeared distinct, as if the deposit had been waterlaid, and lacked the irregularities characteristic of dune sand. The exposure is illustrated in the accompanying fig. 10.

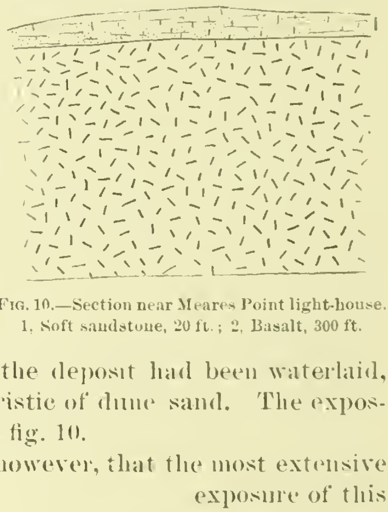


FIG. 10.—Section near Meares Point light-house. 1, Soft sandstone, 20 ft.; 2, Basalt, 300 ft.

It is in the region of Yaquina Bay, however, that the most extensive exposure of this formation was seen. The following section (fig. 11) illustrates what may be seen at Nye Beach. The top of the hill, which is 100 feet above the beach, is dune sand. The edge of the sea cliff is dune sand, resting on a layer containing a stump of a tree in place. Beneath it is chiefly sand, not fully exposed, and the whole

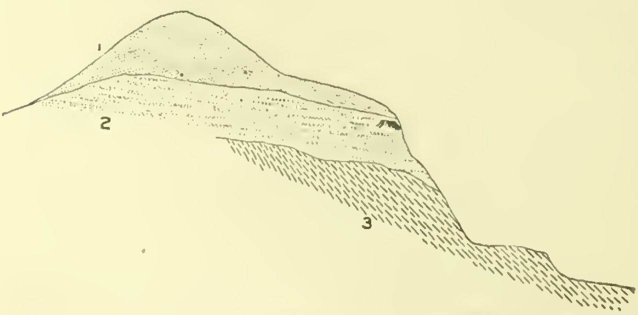


FIG. 11.—Section of Nye Beach Cliff. 1, Dune sand; 2, Stratified sands; 3, Miocene shales.

NYE BEACH CLIFF.

mass rests on the upturned edges of the Miocene shales, which are very fossiliferous and incline seaward at an angle of 20°. About 100 yards farther north the contact of the sand and shales is well exposed. Pl. XI is from a photograph taken at this place, and fig. 12 is a section. The lowest portion of the Pleistocene rests, with marked unconformity, directly on the Miocene, and is composed of angular fragments of shale and sandstone. The upper part of this layer is chiefly sand, partially stratified, and contains wood, logs, limbs, and roots, some of which look as if they were still in the places where they grew. Much gravel and angular fragments are mixed with the sand. Succeeding layers (2) are composed chiefly of sand, with angular fragments and small pieces of wood. It is clearly stratified, with cross-bedding, and in places is stained yellow by oxide of iron. The upper layers (1), having a thickness of about 20 feet, are evenly stratified gray sands, in a horizontal position. The Pleistocene at this exposure has a thickness of about 40 feet, and the lower portions (2 and 3) dip gently eastward with the slope on which they were deposited.

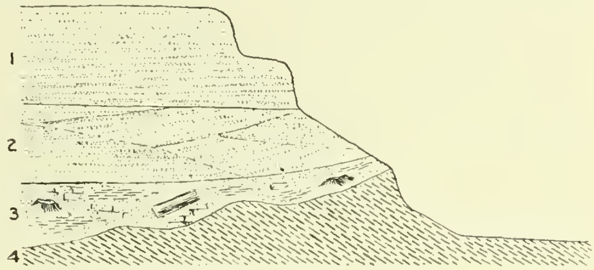


FIG. 12.—Section of Nye Beach Cliff. 1, 20 feet of gray sands, well stratified; 2, Chiefly cross-bedded sands, 12 ft.; 3, Fragments of shale, sandstone, and sand containing wood; 4, Miocene shales.

A short distance farther north, on the beach beyond the mouth of Nye Creek, the following section (fig. 13) exposes about 35 feet of strata. Beneath 18 inches of soil is a bed of sand 6 feet thick, and next below it is a bed of gravel, partially indurated, 5 feet thick. Then come 10 feet of yellow sands with occasional pebbles, and the bottom of the series is not exposed. The exposure is of interest when compared with the others, in containing a bed of well-rounded pebbles. This bed, like another near by in the same bluff, is of small lateral extent, yet it is well interstratified with sands.

FIG. 13.—Section of Nye Beach Cliff. 1, Soil. 18 inches; 2, Sand, yellow and gray, 6 ft.; 3, Gravel, 5 ft.; 4, Sand, with occasional pebbles, 10 ft.; 5, Talus.

The same series of strata is well exposed near Newport, where the grade is cut through the hill toward Nye Beach. The cliff exposes about 80 feet of strata, in which sand prevails, but layers of gravel are common toward the top. Near the base the beds are finer and some of the layers contain considerable vegetal matter, among which are numerous cones. These have been examined by Mr. Knowlton, who pronounced them *Picea stichensis* Carr., the tide-land spruce, which reaches its greatest development to-day in the region about the mouth of the Columbia, but extends as far north as Alaska. Professor Condon called my attention to this locality, and informed me that he had collected a number of marine mollusks here, indicating that the deposit was laid down in the sea.

If marine shells are generally scarce in the Pleistocene deposits about Yaquina Bay, there is one locality, to which my attention was directed by Professor Condon, where they are abundant enough to make up for the deficiency elsewhere. It is in a small recess of the cliff near the Point, about one-half mile southwest of Newport. The section at that place, which represents nearly 100 feet in thickness, is illustrated in fig. 14. The upper layer is wind-blown sand; below it is a thick mass of stratified, yellowish sand, which is sometimes partially cemented so as to form a soft sandstone. It closely resembles material in the upper portion of the section represented in fig. 12. Below this, partly concealed by talus, comes a mass of clay which extends to the bottom. It is in places distinctly stratified, and contains a multitude of marine shells, of which a large collection was made. This clay rests unconformably upon the irregular surface of the Miocene shales, and near the contact, is composed chiefly of shale fragments. A log lies confined along the western contact, which is plainly in view. On the eastern side of the exposure the large mass of talus conceals nearly everything. The small portion of the contact between the shale and the overlying clay was laid bare by excavating. At the top of the clay there is a weed covered bench which looks as if formed by a landslide; but a little examination of the composition, structure, and relative position of various parts of the section here exposed shows that this can not be so. The bench, instead of being produced by a landslide, is due to the presence of springs. The water, which readily percolates the overlying beds of sand, reaches the impervious clay, which drains it to the surface, where it washes away the sand to produce the bench.

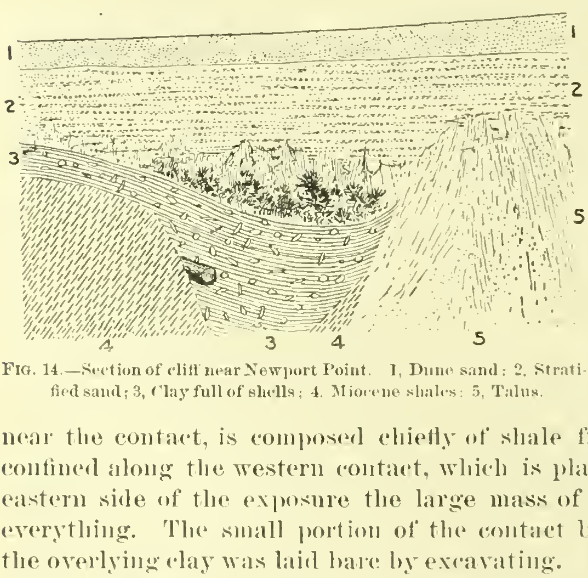


FIG. 14.—Section of cliff near Newport Point. 1, Dune sand; 2, Stratified sand; 3, Clay full of shells; 4, Miocene shales; 5, Talus.

The great abundance of shells, among which Dr. Dall recognized *Monia macroschisma* Desh., *Macoma nasuta* Conr., *Saxidomus aratus* Gld., *Tapes staminea* Conr., *Zirphaea crispata* L., and *Purpura crispata* Martyn., all of which are living forms, shows not only that at least the

VIEW LOOKING NORTH FROM FOREST GROVE.

basal portion of the mass is of marine origin, but that it is of Pleistocene age. In the upper part of the clay that contains shells a cone was found like the cones at the base of the bluff at Newport. Both exposures occur in the same bluff one-half mile apart, and this common fossil serves to connect them still more closely.

From the heights, near the schoolhouse at Newport, looking southeast across the bay, Hinton Point is in fair view. It is well stratified from base to summit. In the upper three-fourths of the bluff, according to Professor Condon, who has examined the locality, the deposits are sandy, corresponding to those exposed at Newport, but beneath them the horizontal strata are argillaceous. The bottom of the clay is not exposed. It lies below the bottom of the bay. Between the sand and clay water escapes, as at the locality just noted, one-half mile southwest of Newport. Professor Condon has collected a large number of fossils from the clay bed at Hinton Point, and reports that Macoma and other members of the same family are abundant. He regards the basal portion of this section as probably Pliocene. The only fossil collected from the Pleistocene north of Newport Point was at the foot of the bluff near the mouth of Nye Creek. James Storrs found in the sand fallen from the cliff a large tooth which Mr. F. A. Lucas, of the National Museum, has determined to be that of a mastodon, probably *Mastodon americanus*, and certainly of Pleistocene age.

East of Newport, on the road to Toledo, the Pleistocene deposits form the surface of the approximately level country (peneplain) for about 2 miles, attaining an elevation of 350 feet above the sea level. They appear to have their greatest development close to the mouth of Yaquina Bay; to the northward, along the coast beyond Cape Foulweather, they are not well exposed. The character of the Pleistocene deposits about Yaquina Bay indicates that at least the lower portion of the deposit was beneath the sea, otherwise it could not include such abundant evidence of marine life and yet be free from indications of human accumulation. Concerning the overlying sands, containing the mastodon tooth and cones, the evidence is not so clear. Certainly land was close by. In the case of the gravels, especially those near the mouth of Nye Creek, their distribution suggests that they represent streams wandering over sand flats to the sea. We see the same sort of deposits at many places along sandy beaches to-day where small streams enter the sea.

Going now to the Coos Bay region, we find similar deposits, but not so well exposed as about Yaquina Bay. Southwest of Empire, at Fossil Point, by the mouth of South Slough, a series of soft beds 14 feet in thickness overlie Fossil Rock, as shown in fig. 7. They are chiefly sand, and no fossils nor conspicuous marks of stratification were observed in it.

Elsewhere about Coos Bay the Pleistocene is either absent, very thin, or not well exposed. Farther southward, however, there are several exposures in the valley of the Coquille. One of the best is along the railroad 2 miles northwest of Coquille, where, in a bluff 30 feet high, there is a fine outcrop of well-stratified sands. The summit of the exposure is at least 50 feet above the sea.

If now we take a general view of the Pleistocene deposits along the coast, it is evident that when these were laid down by the sea the place they now occupy was covered by the ocean, and the land along the coast must have stood at a lower level than at present. The amount of this depression is indicated by the height of the deposits above the present sea level. As far as may be judged from what is already known of the Pleistocene along the coast of Oregon, the depression was at least 200 feet, and probably much more. Our lack of knowledge concerning the upper limit reached by the water upon the ocean side of the Coast Range during the Pleistocene is due to the difficulty of discovering the record, on account of the dense forests and soft rocks, and also in a large measure to the very limited observations that can be made during a hasty reconnaissance through such a country.

It gives me much pleasure to call attention, in this place, to the work of Prof. Thomas Condon, the veteran geologist of the Northwest, who was formerly State geologist of Oregon, and who has contributed more than any other man to what is known of the geology of that State. He has traced the Pleistocene deposits from the mouth of the Columbia, not only north to beyond Shoalwater Bay, but also eastward far up the Columbia and into Willamette Valley, where he named the water body in which these sediments were laid down "Willamette Sound."[1] In some of the bluffs along the coast of Washington, Professor Conond has "found masses of buried forest trees, trunks, leaves, and seeds, so buried in clay, and so well preserved, that the spruce cone, fragile at all times, is scarcely discernible from one of last year's fruitage drifting in the neighboring waters. From these vegetal remains, as from those of the shellfish, the same truths are taught, for the trees are the same in kind as those now growing on the bluffs 100 feet above them." Of the marine shells found in these strata, Professor Condon remarks:

> The oyster is very abundant among them, and the shells of most of them are neither broken apart nor waterworn, as they would have been had they drifted here from some other locality. They evidently lie here as fossils, on the same bed they occupied while living; oysters then, as now, rarely bed in waters more than a few feet in depth. The common cockerel—another lover of shoal water—is also abundant among these remains, and, like the oyster, lies fossil where it lived; the opposite valves often now occupying the very positions relatively that they held while living, so, too, with the members of the clam family, whether mactra, or solen, or venus—all are evidently in their native beds, where they lived and died.

The thickness of these deposits, which at Ilwaco, as before stated, is only 14 feet, at some points on the beach farther north is 100 feet. The upper layers have the finest material and fewest fossils, indicating, as pointed out by Professor Condon, that the land was subsiding while

[1] The Overland Monthly, Vol. VII, pp. 468-473.

VIEW LOOKING SOUTHEAST FROM 2 MILES BELOW MIST, ON THE NEHALEM RIVER.

deposition was progressing, and that the final deposits were laid down in the deepest and quietest waters. At that time the topmost bed of this deposit was at a considerable distance below the level of the sea, at least 200 feet below the present level of that bed on the land.

If the whole of western Oregon subsided 200 feet in all parts, so as to restore at least in some measure the conditions of land and sea which obtained during the Pleistocene epoch, it is evident that the sea would flow in over the land, making a large bay of the Columbia and extending up the valley of the Willamette as far as Salem. The Pleistocene water body in its general outlines must have resembled Puget Sound, and to designate it specifically, as already indicated, Professor Condon called it Willamette Sound. The fertility of the Willamette Valley is largely due to the sediments deposited in it during the time it was a sound, and some of the plains and prairies may then have been formed.

FIG. 15.—Section of Portland Heights near Gambrinus ravine. 1, Clay; 2, Basalt.

The data for the accurate determination of the depth of the water in Willamette Valley have not yet been fully made out, but the evidence already known to Professor Condon indicates that the water extended as far south as Spencers Butte, 3 miles from Eugene. Judging from the height of the terraces on the Columbia near the mouth of the Des Chutes, he estimated the depth of the water over the place where the city of Portland now stands to have been 325 feet. This may well be, and yet when we study the deposits of which the hills about Portland are composed a much greater depth of water is indicated. During a brief stay in Portland a rough section was made up the slopes of the ravine from Gambrinus. It is illustrated by fig. 15. The city is largely upon the modern flood plain of the river, and is, at least at a number of points—for example, on Washington street, near the Oregonian Building—made up chiefly of clay. The lower portion of the hill, above the general level of the city, is made up of basalt, with occasional masses of fine sediments, showing traces of stratification. The upper portion of the hill, extending from the top of the lava, at an elevation of about 310 feet, to the general plain above, which is at an elevation of nearly 660 feet above the sea, is fine, argillaceous sediment closely resembling the loess of the Mississippi Valley. It is in places distinctly stratified and was evidently laid down under water. If this material was deposited in the Willamette Sound of Condon, as appears to be the case, the depth of the water at Portland must have been not less than 600 feet. At present too little is known of the geology of the Portland region to assert that the fine sediments on the heights immediately west of Portland were deposited at the same time as those along the coast.

At the north end of East Portland, near Albino, a bluff exposes the section shown in fig. 16.

The 40 feet of coarse sand above is well stratified, but irregular and cross bedded. This, with the 4 to 10 feet of conglomerate next below, indicates strong, shifting currents. The lower 30 feet of the exposure is made up of sand, pebbles, and bowlders irregularly intermingled. At the base of the cliff, and occasionally within it, are found bowlders of soft gray or yellowish sandstone, very like the Tertiary sandstone exposed at various places in western Oregon. No fossils were found at this point, but Dr. David Raffety gave me a fragment, collected from the gravel at Brooklyn Mills, that contains *Arca microdonta* Conr., a common Miocene form. Brooklyn Mills is at the south end of East Portland. The bluff, in general composition and position, is practically a continuation of the one at Albino. The fossils found at Brooklyn Mills are apparently in a small bowlder derived from the Miocene, and indicate that the gravels in which the bowlders occur are of later age than the Miocene. They are doubtless Pleistocene, and probably younger than the high-level sediments on the opposite side of the river. The fossiliferous Miocene in place is not known to the writer nearer Portland than the Scappoose, in Columbia County, or Dilley, in Washington County, about 25 miles away. It is probable, however, that the same series of strata occur at no great distance south of Portland, and in the Willamette Valley [1] and in the hills to the westward, and, furthermore, they probably extend beneath the city, where they are covered by later deposits.

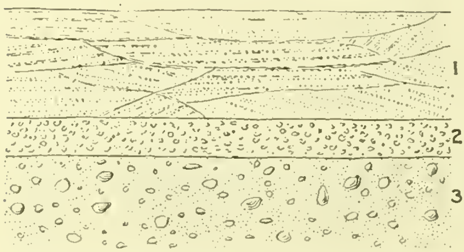


FIG. 16.—Section of cliff at Albino, near Portland. 1, Sand; 2, Coarse gravel; 3, Sand, pebbles, and small bowlders.

At various places along the western side of the Willamette Valley, between Forest Grove and Corvallis, a number of bowlders of granite and schist were observed under conditions that strongly suggest transportation by ice, probably in the form of icebergs, floating upon the Willamette Sound.

The first one noted was upon the hill slope near the county stone quarry, a mile south of Dilley, at an elevation of 120 feet above the sea. The bowlder is of biotite granite, and is about $2\frac{1}{2}$ feet in diameter. Chloritic bowlders were seen near Amity, at an elevation of 190 feet. A few miles north of Corvallis granite bowlders occur, and 12

[1] In the Trans. St. Louis Acad. Sci., Vol. 1, 1860, p. 121, Shumard describes a Miocene Leda from a few miles south of Oregon City.

VIEW LOOKING TOWARD SADDLE MOUNTAIN FROM YOUNGS RIVER BELOW OLNEY

miles southwest of that city bowlders, not only of granite but also of glaucophane schist, were seen by the roadside at an elevation of over 250 feet above sea level. No striæ or other marks showing glacial origin or ice transportation were seen on the bowlders, but that they are erratics carried there from the mountains is evident, for no such rocks are known in the places where they occur. Mr. W. A. Pomeroy, of Oswego, Oreg., informs me that in the vicinity of the Prosser mine, 8 miles south of Portland, there are angular bowlders of syenite, ranging in weight from a few pounds to several hundred, widely scattered in valleys and on the tops of hills and knolls 800 to 1,500 feet high.

During the Glacial period, as pointed out by Professors Newberry, Russell, and others, glaciers of the Cascade Range were large, and extended almost if not quite into Willamette Valley; for those of Mount Shasta in California at that time reached the very base of the mountain upon the western side. Thus small icebergs could have been readily formed to carry bowlders of rocks from the western slope of the Cascade Range and float upon the broad expanse of Willamette Sound. As they melted they dropped their loads of stones to the bottom, where the stones now appear scattered throughout the valley.

Hitherto in the consideration of the Pleistocene of Oregon, attention has been confined to matters growing out of the sediments deposited at that time. There is, however, another point of view, and that is from the land surface which furnished the sediments.

The streams flowing over the land, especially during freshets, carry much mud, sand, and other detritus into the sea, where it is deposited. Thus it is that the land is gradually being washed away and reduced in elevation toward the sea level. The level of the sea is the baselevel, lower than which the land can not be eroded. Practically it is only possible to reduce the land by erosion to peneplain (almost a plain), which is nearly at the level of the sea. By this process the mountains are gradually worn down to hills and then reduced to knolls, so that the landscape ultimately becomes a gently undulating plain.

To remove mountains and reduce the country to a peneplain by the slow process of erosion, requires that the land and sea should remain in the same relative position for a long time. The development of the peneplain begins along the principal water courses, where the erosion is most rapid and first reaches approximately the baselevel of erosion. Thence, as long as the land does not change its elevation with reference to the sea, the peneplain will gradually spread, and, unless interrupted, will extend until it embraces the whole landscape.

A glance at the Coast Range of Oregon, which this reconnaissance afforded, discovers traces of peneplains at many points throughout the range. Such a plain may be seen in the general view looking north from Forest Grove, where, as shown in Pl. XII, the long, even profile of the divide, about the head of Gales and Dairy creeks, is well marked. From an outlook to the west and southwest, immediately above Boos's rock quarry, 5 miles southwest of Forest Grove, a well-marked peneplain is seen. Flat-topped Quarry Hill is in the plain, and has an elevation of about 525 feet above the sea, and from this point the peneplain rises westward toward the central portion of the Coast Range. The Tualitin, on its way to the Willamette, has cut a deep valley across this plain. At the quarry Miocene fossils are abundant, and the sandstones dip at an angle of 34°, so that the plain is evidently one of erosion across the upturned edges of the Miocene. The formation of the peneplain was not complete, for there are peaks and ridges which project above its general level. Adopting the general term "monadnocks," first used by Prof. W. M. Davis to designate such well-marked elevations as project above the peneplains, it may be said that monadnocks are not an uncommon feature in the northern portion of the Coast Range, and that the peneplain terminates against them quite abruptly.

The dense forest covering throughout the Coast Range renders extensive views uncommon, but wherever obtained traces of an elevated peneplain may generally be seen. This is especially true about the northern portion of the Coast Range in Oregon. A general view toward the southeast from near Mist, with the Nehalem River in the foreground, is shown in Pl. XIII. A portion of an elevated peneplain appears at the head of the valley.

The uplands, excepting monadnocks, are generally flat-topped, and the peneplain of which they form a part is highest near the middle of the range. Along the Military road, now a trail, reaching from Mishawaka to Saddle Mountain and beyond, the peneplain is marked. It ranges in altitude from 1,250 feet near the falls of the Fish Hawk to about 1,700 feet near Saddle Mountain, which rises above the general plain as a distinct monadnock. Its relation may best be seen from a point several miles northwest of Olney, where the following view (Pl. XIV) was taken. The highest point is Saddle Mountain. It rises conspicuously above the general plain, which is shown on the flat-topped hills next nearer to the point of view. These represent the highest peneplains, ranging from 1,200 to 1,700 feet. Immediately north of Olney there is a well-developed plain cut upon the upturned edges of the shales at an elevation of about 400 feet. This plain is of considerable extent to the north and east of Olney, and next below it, several miles farther down the river, is a plain only 50 feet above the tidal flats. The relations of these plains to one another, whether they are simply parts of one great plain separated and displaced by faulting or entirely distinct plains developed at different periods, have not been definitely determined, although the facts observed indicate that the latter view is correct.

The peneplains already noted about the northern end of the range may be traced more or less distinctly to the southward, but on the whole they are generally less marked. There can be no doubt, however, concerning their reality and the light they throw upon the later

VIEW LOOKING SOUTHEAST ACROSS THE NEHALEM FROM 2 MILES BELOW NEHALEM POST-OFFICE

geological history of the Oregon coast. In a view (Pl. XV), looking southeast across the river from a point about 2 miles below Nehalem post-office, the even-topped hills may be seen bristling with dead timber, and the distant mountains as monadnocks projecting above the general level of the peneplain. A similar view (Pl. XVI) is obtained from Toledo, looking across the Yaquina River. The distant monadnocks are absent, but the all too frequent bristling hills are especially well shown.

The streams of the Coast Range at the present time cut deep canyons down its slopes, and it is evident that the peneplains of that region could not have developed at their present elevation above the sea. At the time of their origin each must have been but little above the level of the sea, and since then, by the upheaval of the land, they were raised to their present position. A very rough approximation as to the amount of the upheaval is given in the measure of their present altitude. The greatest elevation of the plain observed was 1,700 feet. It may, however, attain a greater altitude. About the head of the Klatskanie very suggestive level tracts were noted on the road from Pittsburg to St. Helens, on the west side of the divide, at an elevation of over 2,000 feet. Some of the flat tops in that region, however, are due to lava cappings, and the surface beneath may not be so regular. The uplift may have been greater in some places than in others, but of this the evidence is not conclusive, as there may have been considerable differences originally in the elevation of the higher and lower portions of the peneplains.

The upper peneplain is cut upon soft sandstone and shale, and the structure is such as to suggest that only a comparatively small mass of these soft strata was worn away in forming the peneplain. These features indicate that the work was accomplished in a relatively short time, and that the resulting deposits along the coast were of comparatively small amount, although it is believed that other deposits of Post-Miocene strata may yet be discovered upon the slopes of the Coast Range.

At the time of the greatest depression, when the most extensive peneplain was developed, the Nehalem and the Umpqua rivers may have initiated their courses across the Coast Range and maintained them, notwithstanding the upheaval of the Coast Range across their valleys. If so, they were able to cut their canyons across the range as rapidly as the elevation required them to do in order to drain directly across the range.

As the land was raised from the conditions under which the peneplain was formed, the retiring ocean, in favorable positions at various levels, left its marks as wave-cut terraces or elevated beaches, with sea cliff and shells and other deposits. River terraces, well developed along the Nehalem and other streams, record stages in the progress of valley making.

The soft sandstone and shales of the Miocene are not well suited to preserve such records upon steep slopes, although they may be observed at a number of places. The peneplain at the 400-foot level, southeast of Astoria, is well marked, and at other points along the coast traces of beaches and terraces were seen most frequently about that elevation above the sea, although in most cases no attempt was made to more than roughly estimate their altitude. A well-marked peneplain about this elevation is the dominant topographic feature between South Slough and the sea near Coos Bay. A good view of it is obtained on the road from Empire to Bandon, and near the edge of this peneplain, especially toward the Coquille, there are important deposits of auriferous black sand. It is possible that at about that level the previously raised land stood still for a time, allowing the erosive agents to make a deeper record. But if it halted at all in its upward course it did not stop long at any level, and the upward movement continued until the land was raised above its present position.

At that time the coast of Oregon was farther westward, and the land included a strip about 5 miles in width that now lies beneath the ocean. Across this border the rivers once flowed and cut channels to the sea. The numerous soundings made by the United States Coast and Geodetic Survey along the coast of Oregon show that an old channel of the Columbia still exists beneath the sea from the present mouth of the river to a point where the bottom falls off rapidly and the deep sea begins. My information upon this point was derived from Prof. George Davidson, who for many years had charge of the work on the Pacific Coast.

The last movement of the land by which the Oregon coast came to its present position was one of subsidence. The sea advanced over the land, and the border of the coast already referred to became part of the bottom. This movement had a marked effect upon the rivers. They are drowned on the lower portion of their courses, and the tide comes far inland. In the case of the Coquille the tide follows up the river to Myrtle Point, a distance of 40 miles.

PART II.

ECONOMIC GEOLOGY.

Having considered the region embraced within the reconnaissance with reference to its geological structure and history, we can now more intelligently turn our attention to the deposits of economic importance associated with the various formations. The coal fields will be first described, and then the occurrence of iron ore, gold, platinum, and building stones will be briefly considered.

VIEW FROM TOLEDO, LOOKING ACROSS THE YAQUINA.

THE COAL FIELDS OF WESTERN OREGON.

Oregon has long been known as one of the coal-producing States of the Pacific Coast, but until this season no systematic attempt has been made to take a comprehensive view of the whole field to determine the geological position and areal distribution of the coal-bearing rocks. This could be done at the present time only in a preliminary way, inasmuch as the topographic maps of the country, upon which the productive districts could be outlined, have not yet been made. When the topographic surveys, already well advanced about Roseburg and Coos Bay, shall have been extended over the whole of Oregon west of the Cascade Range, and the maps published, it will be possible to show definitely the lateral extent of the coal regions.

The coal fields of Oregon so far as yet known all lie west of the Cascade Range and north of Rogue River. Most of them are among the mountains generally known in Oregon as the Coast Range, but others occur at the western foot of the Cascade Range. Four fields will be noticed here: (1) The Upper Nehalem coal field, in Columbia County; (2) the Lower Nehalem coal field, in Clatsop County; (3) the Yaquina coal field, in Lincoln County; and (4) the Coos Bay coal field, in Coos County. Traces of coal have been found in many other parts of the State, and some of these occurrences will be noted, although little can be said concerning their extent. It is not at all improbable, however, that when the detailed explorations of the Geological Survey are made other fields of considerable size will be discovered. Such explorations are necessarily slow. The luxuriance of the undergrowth, especially near the streams, and the abundance of fallen timber render the forest in many places upon the upland slopes of the Coast Range a veritable jungle. Exposures are few and meager and their rarity greatly increases the difficulties which beset the geological observer.

THE UPPER NEHALEM COAL FIELD.

The Upper Nehalem coal field is in Columbia County, within the drainage of the upper portion of the Nehalem River. It extends northeast and southwest a total length of about 13 miles, and has a width of 1 to 2 miles. The coal of this field is exposed upon the forks of Pebble Creek, the east fork of the Nehalem, and the Clatskanie.

Beginning at the southwest end of the field, in sec. 34, T. 4 N., R. 4 W., there is a bed of coal which has been opened in the main fork of Pebble Creek near the county line. The pit, which once exposed the whole thickness of the bed, had been filled up by the stream, but I was informed by Mr. N. C. Adams, who prospected much of the coal in that region, that the bed is 4 feet 10 inches thick, including a parting of soft yellowish sandstone which measured 4 to 6 inches. At the time of our visit only the upper 18 inches of the bed could be seen.

On a fresh fracture the luster of this coal is brilliant, but soon becomes dull. It has a fine-banded structure parallel to the bedding, and upon exposure to changes of temperature and moisture fissures develop along these planes in the coal, but much of it does not slack. It contains a few nodules of pyrites, breaks readily into flattish pieces, and burns with a bright yellow flame. Analyses numbered 2 and 3 in the table given later are of coal from this locality.

The coal lies between sandstones. In the gray sandstone above, Mr. F. M. Anderson, who assisted me in the examination of nearly all the coal fields, collected a few fossil shells and fish scales. The sandstone is occasionally hard, but not so firm throughout as to make timbering entirely unnecessary in mining the coal.

About 100 yards farther down Pebble Creek, upon the right bank above the stream, apparently the same coal crops out, showing that the strata dip gently eastward.

The best exposure of the coal seen in this field is upon the East Fork of Pebble Creek, in section 23, where the Great Northern Coal Company has opened several drifts along the croppings of the principal coal bed. From any elevated position affording a good general view of the upper portion of the Nehalem Valley, it may be seen that the streams all flow in canyons cut in the broad upland platform, which is almost a plain—a peneplain. The general level of this peneplain bordering the canyon of the East Fork of Pebble Creek is from 1,250 to 1,340 feet above sea level. The canyon in section 23 has a depth of 420 feet, and the steep slopes of its lateral gulches afford some good exposures of the coal beds and associated sandstones.

Nearly midway down the western slope of the canyon, at an elevation of 1,050 feet, two small coal beds occur. The upper contains about 12 inches and the lower 14 inches of impure, dull, platy coal. The beds are 10 feet apart, and both are inclosed in soft sandstone.

Fifty feet lower upon the side of the canyon, and a short distance farther up the stream, are three tunnels, run in a few years ago by the Great Northern Coal Company upon a bed of coal nearly 9 feet in thickness. The longest tunnel follows the bed about 100 feet, and affords a fine exposure of the coal. The coal is generally compact and fine-banded, splitting most readily parallel to the bedding. Near the bottom of the bed the woody structure of the lignite is well preserved. On a fresh fracture the luster is often brilliant, but, with the exception of occasional thin, irregular bands, it soon becomes dull-brown, and upon exposure falls to pieces more or less readily. It lies between beds of rather soft sandstone, which may in places be firm enough to support the roof without timbering. The coal dips gently to the southeast, and a large portion of it lies above drainage, so as to be economically mined. The canyon would afford an easy line for a railroad to the Nehalem River, along which the easiest grade for a railroad toward the coast could be obtained.

Eighty feet below the tunnel already mentioned, by a stream at the bottom of the canyon, another bed of coal crops out. It is from 6 to 8 feet in thickness, contains several sandstone partings, and is overlain by soft sandstone. The quality of the coal is much the same as that in the larger vein above. It has been prospected by the Great Northern Coal Company, but for only a few feet beneath the surface. This bed is inclined at an angle of about 10° in a direction between south and southeast.

About one-third of a mile northeast of this locality, in the next gulch, two beds of coal appear. The upper bed is about 10 feet in thickness, but it is impure below and contains two sandstone partings. Farther down the same gulch is an 18-inch coal, and near it occur numerous fossils similar to those found in the same bed at the lower drift of the Great Northern Coal Company. They resemble the fossils which occur close to the coal in section 34.

Analyses 4, 5, and 6, in the table given later, are of the coal on the East Fork of Pebble Creek. The coals contain an unusually large percentage of ash and sulphur. Fearing that there was some mistake, these determinations were made again, with practically the same result.

The position of the strata on Pebble Creek and the East Fork of Pebble Creek suggests that the coal in section 34 is probably continuous with that in section 23. If so, it should crop out in the ravines in section 27 and the adjacent corners of sections 22 and 26. This view is supported by the fact that the Eocene fossils at the two localities are clearly related, and yet the striking differences in chemical composition tend to show that the beds are distinct.

The thickness of the beds is sufficient to suggest considerable lateral extension, and for this reason the same coal might be expected to appear upon the East Fork of the Nehalem River. In fact, two coal beds have been discovered upon one of the forks of that stream. Mr. A. H. Powell has prospected them in sec. 27, T. 5 N., R. 3 W. At this point the general elevation of the peneplain is about 2,200 feet, and the canyon is over 400 feet deep. The coal is about 5 feet in thickness, and lies between horizontal beds of sandstone. It is shaly, and, judging from its looks alone, appears to be inferior in quality to that of the East Fork of Pebble Creek.

Mr. Powell reports a bed of coal farther down the ravine, about 80 feet below the one just noted, and smaller beds farther up, but on account of landslides, the luxuriant undergrowth, and a large amount of fallen timber we were unable to find them.

Mr. Anderson collected a number of fossil shells near the coal, and it was then thought probable that the same bed continues from sec. 34, T. 4 N., R. 4 W. to sec. 27, T. 5 N., R. 3 W., a distance of nearly 10 miles. According to Dr. Dall, the fossils do not support this view, for in section 37 the shells are apparently of Miocene age, while these of sections 34 and 23 are unquestionably Eocene. So far as the writer is aware, no coal has yet been found on the main stream of the East Fork of the Nehalem, where it ought to be exposed if continuous, as suggested above. In that locality it would be more conveniently located for shipment to the main valley of the Nehalem and the coast.

Fragments of coal have been found on the Clatskanie, showing that the coal beds occur within its drainage. It is most probable that they outcrop near the head of the stream, where it is nearest the coal on the East Fork of the Nehalem.

The upper Nehalem coal field, while it has a length of over 10 miles, is, as far as yet known, not over 2 miles in width, so that the whole area of the field is less than 20 square miles. Nevertheless, with two beds of coal, one 6 and the other 9 feet in thickness, it ought to yield a quantity of coal of commercial importance, if upon practical tests the coal is proved to be good enough to create a demand for it, and if facilities are provided for cheap transportation. At present the best outcrops are not reached by even a poor road.

About a ton of coal from the East Fork of Pebble Creek was packed out and sent to Portland, where it is said to have burned well in stoves, but, so far as the writer knows, its steam producing power has never been measured.

LOWER NEHALEM COAL FIELD.

The Lower Nehalem coal field is situated north of the Nehalem, near the county line between Clatsop and Tillamook.

In sec. 16, T. 3 N., R. 10 W., occurs an 18-inch bed of coal lying between beds of clay. It is near the south foot of Ne ah kah nie Mountain, and is inclined at an angle of 30° southwestward. A short distance farther down the slope is another exposure of coal. It can be traced for 50 feet along the strike and ranges from 5 inches to 14 inches in thickness. It dips at an angle of 30° to the northwest, nearly at right angles to that in the other exposure. There may be two beds of coal here, but considering the softness of the associated strata and the difference in position of the coal outcrops, it is not improbable that the lower exposure is only a slide from the upper. The analysis of coal from this locality is No. 11 in the list.

On another branch of Hodge Creek, about 250 yards to the eastward from the locality just noted, two tunnels have been driven by Mr. J. G. Gerritze for Mr. S. F. Pearson. In one of them a 2-foot pocket of brilliant, homogenous, fine-looking coal was found, which yielded the analysis No. 12 in the table.

On Coal Creek, in sec. 2, T. 3 N., R. 10 W., is an 18 inch bed of coal which lies between shales and strikes northeast and southwest, dipping to the northwest at an angle of 50°. The coal resembles that from section 16, of which it may be a continuation, for a coal of the same character, 22 inches in thickness, is reported by Mr. Frank Steinhäuer from section 10, which lies between, and a similar if not identical lustrous, black 10-inch coal occurs in section 36 of the next township to the north. It lies between sandstone (above) and shale. Analysis No. 13 shows its composition.

No fossils were found in immediate connection with the coal, so that its age is not definitely known, but it appears to be beneath the Tertiary shales exposed near Crawford on the North Fork of the Nehalem.

Sections 16, 10, 2, and 36 are all in a line extending northeast and southwest, and the coal exposed in them may all belong to the same bed. The eoal field, so far as known, has a length of about 5 miles. The quality of the coal is good, but its thickness, so far as yet known, nowhere exceeds 22 inches. It occurs in strata so soft as to render timbering generally necessary, and is inclined at a considerable angle. In view of these facts, notwithstanding its good quality and nearness to tide water, above which it rises only a few hundred feet, it can not be regarded as promising commercial importance.

THE YAQUINA COAL FIELD.

This field is in Lincoln County, north of the Yaquina River, and 6 miles from the coast. It borders Depot Slough upon the west, and has its greatest extent north and south.

A few miles west of Toledo, in sec. 13, T. 11 S., R. 11 W., coal has been found in a number of gulches. At one place the coal is exposed in a tunnel nearly 200 feet in length. It is greatly fissured, and the cracks contain a yellowish coating that makes the coal look muddy. The bed at the end of the tunnel is about 20 inches in thickness. It becomes thinner to the northwest, as the bottom rises in that direction, and it lies between soft sandstones, the top one of which contains marine shells. The inclination of the strata was not accurately measured, but it has been estimated at 20 degrees. Analysis No. 14 is of coal from this locality.

Dr. J. H. Bryant, who systematically prospected this field with a diamond drill, bored a hole a short distance southeast of the tunnel, but I have not yet been informed what he found. In this same neighborhood there are other exposures of coal, but so far as yet known they are small and of no value. In places the sandstones eontain many small films or lenses of coal, and there are all grades in size from this to beds 20 inches in thickness and a mile or more in lateral extent. The character of the deposits everywhere, not only in this field, but in others, is such as to indicate that they are very local and in most cases not of commercial importance.

In sections 36 and 30 of the next two townships to the north several outcrops of coal have recently been prospected with the diamond drill by Dr. J. H. Bryant. One bed having a thin parting of sand is reported to average 3 feet of coal. A sample from this bed was given me by Mr. P. T. Johnson. Its composition is numbered 15 in the list of analyses. The extent of this coal is not yet known, but it is not believed to be great.

Farther northward traces of coal have been found near the head of Depot Slough, and also on the Siletz River, but the outcrops are less promising than those already noted.

The Yaquina coal field has a length from north to south of about 5 miles and a breadth of not over a mile. It contains, apparently, several beds of coal which belong to nearly the same horizon. Although not very far from marine transportation, it does not promise to be of great commercial importance.[1]

THE COOS BAY COAL FIELD.

The Coos Bay coal field is the most important one in the State, and when thoroughly mapped will be a subject for later report. Thus far only a general reconnaissance has been made for this preliminary report and comparison with the other fields.

It is situated in Coos County, upon the borders of Coos Bay, with a length northeast and southwest of at least 20 miles and a breadth of 5 miles, so that its area is not less than 100 square miles. It is probable that future investigations may show this field to be considerably larger, but at present no promising outcrop is known to the writer south of the latitude of Bandon or north of Haynes Slough.

At the southwestern end of the field, near Riverton, a 3½-foot bed of coal has been opened by T. H. Timon. The writer's information concerning this coal has been derived from Mr. Timon, and from Mr. E. C. Barnard, of the United States Geological Survey, who examined the mine. A tunnel is driven in the coal for several hundred feet. Mr. Timon estimated the output for 1895 at 4,000 tons. It is said to be good steam coal. The bed is only about 100 feet above the tide water, one-fourth of a mile away, and dips to the northeast at an angle of about 18°. The coal is overlain by sandstone, has a small parting of the same material, and rests upon shale. The compact character of the coal permits it to be mined in large fragments. Its analysis, from a sample furnished by Mr. Timon, is No. 17 in the table. The good quality of the coal and the economy with which it can be mined and shipped, combine to render this a promising portion of the field. The shallow bar at the mouth of the Coquille is, however, a serious impediment to commerce. Mr. Timon says that there are a number of persons prospecting for coal in that region, and that several other veins will be worked when the entrance to the Coquille is improved sufficiently to afford better freight rates.

Messrs. Fred. F. Sharpless and Horace V. Winchell examined the

[1] Mr. John Ray, of Corvallis, has prospected for coal and collected numerous fossils in Benton County, and he has published two small papers, entitled "Hints on coal bearing formations in Benton County" and "The older Coast Range." I desire to express my indebtedness to Mr Ray for much valuable information concerning that region, especially as to the occurrence of fossils

auriferous black sands and coal deposit in part of the country lying immediately north of the Coquille River. They report a bed of coal near Riverton with an average thickness of 33 inches. Its outcrop is about 100 feet above the river, and the dip of the bed is 8° to the northwest. It has been developed by an open pit and a tunnel about 20 feet in length. Sharpless and Winchell have made three analyses of this coal, and the results are numbered 18, 19, and 20 in the list.

The dip of the strata on the Coquille near Lampers Landing is northward at an angle of 45°. They are full of fossils like those near Marshfield, and suggest that the coal of Iowa Slough, which overlies them, may be of the same horizon as that of the Newport mine.

Sharpless and Winchell report an important bed of coal about 4 miles northwest of Riverton, in sec. 23, T. 27 S., R. 14 W. Their report has not yet been published, but I have been permitted to read it, and make the following and other extracts:

> At this point a tunnel is found running into a hill for 150 feet on the strike of a coal seam. This coal bed has a thickness of at least 7 feet, and perhaps 9 or 10. Four feet of coal lies above a parting which is 4 inches thick, and 3 feet of it below this main parting. There is another shaly parting of 2 inches 3 feet above the main parting. The dip of this coal is east 25°, which would rapidly lead to a considerable depth in mining conditions. The hill rises about 100 feet above the tunnel, and could be easily drained for 50 or 75 feet below it. Other coal seams are said to occur in the same hill, but were not examined.

The analyses of this coal, furnished by Sharpless and Winchell, are numbered 21, 22, and 23 in the table.

Six miles north of Riverton and about 3½ miles northeast of the occurrence last described is the Beaver Hill mine, opened within a year, and now actively operated by R. A. Graham, with J. L. Parker as superintendent, and a large force of men. A branch of railroad 1½ miles in length has been built to it from the main line of the Coos Bay, Roseburg and Eastern Railroad near Coalton.

The bed is somewhat variable in thickness and contains two thin partings of sandstone. The associated sandstones between which the coal appears are sometimes fossiliferous and comparatively soft, although in many places firm enough to stand without timbering.

The coal is brilliant black, with homogeneous structure, and has the composition given under No. 24 of the table. The large force of men is employed chiefly in developing, and the mine has not yet entered fully upon its career as a producer. During 1895, 12,000 tons were shipped.

The strike of the bed varies considerably, but generally it is in a northeasterly-southwesterly direction, with a variable dip to the southeast at an angle of about 40°. The strata here are much disturbed, and the high angle at which they incline greatly increases the cost of mining the coal. Upon the surface the Beaver Hill bed has been traced along the strike for 8 or 10 miles.

The only coal mine of Oregon which has been continuously operated for a considerable time is the Newport. It has been worked for over forty years, and it owes its success not so much to the quality of the coal as to economical mining and management. It is now operated by Goodall, Perkins & Co., of San Francisco, with Mr. William Campbell as superintendent. The writer personally examined only one tunnel of the mine. All his information with reference to other portions of the mine and to the Newport basin was kindly furnished by Mr. Campbell. The location is in sec. 9, T. 26 S., R. 13 W., where a ravine has cut into the middle of the shallow basin containing the coal at an elevation of about 100 feet above sea level. The bed of coal is about 5 feet 8 inches in thickness, and has two small sandstone partings of 6 inches each, leaving 4 feet 8 inches of solid coal. The total thickness varies greatly from place to place, especially about the islands which the coal encircles within the basin. The coal appears to be contained in a shallow, boat-shaped fold, which, according to Mr. Campbell, is about 4 miles long and $1\frac{1}{4}$ miles broad. The coal is said to outcrop upon the surface around the edge of this synclinal basin (the Newport Basin), and toward its center the coal is covered by 100 feet of sandstone. The opening of the mine is in a gulch near the center of the basin. The coal appears to dip gently toward this point from all directions. A stationary engine upon the outcropping edge of the bed pulls the empty cars into the mine, and the loaded cars run from all parts of the mine to the opening by gravity. The slopes of the ravine in which the mine opens afford a convenient means for utilizing gravity as an aid in sifting, sorting, weighing, and loading the coal on the cars, which carry it by a comparatively gentle grade down Coal Slough to large bunkers on Coos Bay near Marshfield, where it is easily transferred to vessels. The position of the coal bed and its situation with reference to the sea are very important factors in the cheap production of coal from the Newport mine.

The coal of this mine is brilliant black, breaking into small cubical blocks. In some places it is homogeneous, and at others it is irregularly streaked parallel to the bedding plane. The character of the vegetation from which the coal originated is shown by the occurrence of logs, which are sometimes completely changed to coal, and yet the woody structure is fully preserved. An analysis of a piece of coal in which the woody structure is distinct is No. 25 of the table. A comparison of this analysis with the one numbered 26, which was made of coal selected by Mr. Campbell as a representative sample of the Newport mine, will show how completely the wood has been changed to coal. A comparison of these analyses with those numbered 27 and 28 shows an improvement in the quality of the coal. What is now mined contains considerably less moisture and sulphur than that analyzed by Mr. Price.

The bottom upon which the coal rests is chiefly sandstone, and it is occasionally quite irregular, sometimes rising into the coal and cutting it off completely. The coal encircles several small areas; these were small islands in the swamp in which the vegetation accumulated to form the coal. One of these islands is shown at the mouth of the mine near the center of the basin, where the coal runs out completely and the limiting sandstones come together with only dark tracings to mark the boundaries.

The outcropping coal about the edge of the Newport Basin shows that the swamp in which the coal originated was of greater extent than the basin. The swamp may have extended more or less continuously throughout the whole coal field from the Coquille to North Slough. The rocks at that time were lying horizontally. The Newport basin originated at the time the rocks were folded. The upward folds, or anticlines, were largely washed away, but the downward folds, the synclines or basins containing the coal, have been preserved. That the Newport coal is in a shallow syncline there seems to be no doubt from the testimony of the mine itself, for the coal is reported to have been sufficiently prospected or removed to expose the form of the fold. The structure of the remainder of the coal field has not yet been wrought out. The dips of 18° on the Coquille and 45° at the Beaver Hill mine show greater disturbance than at the Newport mine.

During the summer of 1895 there were only three mines in active operation, the Newport, the Beaver Hill, and the Timon. Others have been operated in the past, and some continued several years. The Eastport mine, immediately north of the Newport, according to Mr. W. A. Goodyear,[1] was active in 1876 and produced considerable coal. He reports as follows:

> The aggregate thickness of the coal mined ranges from 4 to 5 feet, averaging about 4½, in two benches of nearly equal thickness with a stratum of soft shale between them whose average thickness is about 6 inches, though it ranges in different parts of the mine from 4 to 10. Above the upper one of these two benches comes a stratum of shale, generally about 1 foot in thickness, and immediately over this again about 1 foot of coal.[2]

The Newport mine is evidently on the same bed of coal as that formerly worked in the Eastport mine.

Mr. Goodyear reports a new mine in 1877, immediately south of the Newport mine. A tunnel was driven some 500 or 600 feet upon the coal bed.

> At a point where the tunnel was commenced there was no visible outcrop whatever of the coal at the surface of the ground, but a few feet beneath the surface a dark colored streak began to show itself, which grew rapidly thicker and purer until within 100 feet from the mouth of the tunnel it had developed into a bed of good coal about 4 feet thick. Beyond that point, as far as the tunnel has yet extended, this bed will furnish from 4 to 4½ feet of clean, hard coal, of a quality as good as the best hitherto furnished by the Coos Bay mines. The strike of the bed is about N. 18° E. true course, and its dip is about 8½° to the east. It has in the middle of it a streak an inch or two in thickness of soft clay "mining;" but the remainder of the bed is good, clean coal, which separates easily from the roof and floor, and as, furthermore, both roof and floor consist of good, solid sandstone, the coal can be mined from this bed for a little less cost than it can at either of the other mines, where the

[1] The Coal Mines of the Western Coast of the United States, 1877.

[2] Loc. cit., p. 87.

roof is not so good. So far as can be judged from surface indications also, there is every probability that the mine will prove an extensive one, and that the quantity of the coal which can be cheaply extracted from it will be large.[1]

This mine closed some years ago for reasons unknown to the writer.

Five miles directly north of Marshfield and between North Slough and Jordan Point, or Kentuck Slough, is the Glasgow mine, which has been operated, and much money has been devoted to prospecting and developing it. The mine is not open now, but Mr. William Sharp informs me that there are two beds of coal, one 180 feet above the other, reached by separate tunnels. The upper bed has about 5 feet of coal, with two partings; while the lower bed has about 9 feet of coal, with four small partings. Mr. Goodyear examined this locality in 1872, when the Hardy mine was in operation. The strike of the bed of coal exposed in the long gangway was north and south, with a dip of 16° to 18° to the westward. Although the coal outcropping at the surface appears to be of fair quality, in the gangway below it was found to be soft, and crumbled very badly on exposure.

The bed itself is, in all probability, identical with the one in the Eastport and Newport mines, as it consists of the same three layers of coal with streaks of clay-rock between them, arranged in the same order, and preserving very nearly the same thickness, both relatively and absolutely, as at those mines.[2]

This bed, upon which the Hardy mine is located, is evidently the upper bed noted by Mr. Sharp.

In sec. 23, T. 26 S., R. 13 W., a few miles from the head of Isthmus Slough, the Utter mine was operated about twenty years ago, and produced, according to Mr. Utter, about 10,000 tons of coal. The coal bed is said to have been 6 feet in thickness, with a small parting of shale near the middle. The lower half of the coal is soft and of little value, but the upper half is of much better quality. The strike of the bed is nearly east and west, with a dip of 17° southward. On account of the quality of the coal and the cost of production and transportation the mine has been closed for years.

In the next section to the westward (22) the North Pacific Coal Company began operating apparently upon the same bed that occurs in the Utter mine, but with no better success.

Farther north, but upon the east bank of the Isthmus Slough, near the line between sections 34 and 35, T. 25 S., R. 13 W., a mine known as the Henryville mine was expensively opened and outfitted. The plant is now practically in ruins. An incline was driven for a distance of 1,000 feet or more at an angle to the dip, upon a thick bed containing much carbonaceous material, but without finding coal sufficient to pay for mining. At this point the strike of the strata is north and south and the dip easterly. The angle of the dip is greater and the beds are more disturbed by faults than in the Newport mine. The disturbed strata are perhaps best exposed upon the surface and in a slope sunk in

[1] The Coal Mines of the Western Coast of the United States, 1877, pp. 91–92.

[2] Loc. cit., p. 94.

the southwest quarter of section 25, where an utterly fruitless attempt to find coal was made by the same company. Large sums of money have been wasted in the Coos Bay region upon expensive plants before the value of the coal was assured by thorough prospecting. In prospecting any coal field the first step should be to prospect thoroughly the surface outcrops, and if this does not completely settle the commercial value of the deposit, then consideration should be given to the ultimate cost of running an opening as compared with that of boring a hole with a diamond drill to determine what is beneath the surface. The diamond drill in certain cases is a valuable means of prospecting.

The operators of the Newport mine are boring a hole to determine the composition of the strata underlying that region. The strata are but gently inclined and the conditions are especially favorable for such prospecting. Mr. Campbell, superintendent of the mine, informed me that the drill had passed through 300 feet of sandstone and 500 feet of shale. The sandstone is on top, and the top of the boring is about 100 feet below the Newport coal bed. The intervening rock is sandstone, so that there is positive evidence, in the region of the Newport mine, that no valuable coal occurs within 900 feet below that bed. In the middle portion of the Newport basin the coal is overlain by 100 feet of sandstone, making the measured section, beginning at the top: 100 feet of sandstone, 5 feet of coal, 400 feet of sandstone, and 500 feet of shale. The sandstone core showed many fragments of fossil shells, so that it is known that the rock beneath the coal is full of fossils. Fossils are also abundant in the beds immediately overlying the coal in the Newport mine. In many places they were collected from the roof of the tunnel. Among them Dr. Dall recognized *Lutricola unda* Conr., Ostrea, and Tellina, but none of the forms are sufficiently characteristic to determine the age of the beds. The position of the fossiliferous strata at Marshfield and Jordan Point suggests that the coal beds are of Eocene age, but their gentle inclinations, especially in the Newport basin, and the occurrence of similar rock rich in Miocene fossils to the westward near South Slough, leave their exact geological horizon in doubt.

Coal has been discovered a few miles south of Empire, and also at other points within the Coos Bay region; but a thorough study of this field can not be made until the surveys now in progress shall have been completed.

There is, however, one locality that should be mentioned on account of its geological rather than its economic importance. On the coast, about three-fourths of a mile east of Cape Arago, is a thin bed of coal, from which a number of tons were obtained for use at the Arago lighthouse. It is interstratified with a highly tilted series of shales and thin-bedded sandstones which contain numerous characteristic Eocene fossils, and it is evidently of the same age.

OTHER OUTCROPS OF COAL.

Besides the exposures of coal within the fields already noted, there are numerous other outcrops of greater or less importance within the State. They are usually isolated occurrences, and except in a few cases can not be grouped together.

Mr. William Sharp, who has prospected much for coal in Coos County, has informed me that a bed of coal occurs near the head of Big Creek, in T. 29 S., R. 10 W., and that it crops out on the Middle Fork of the Coquille a short distance west of the mouth of Sandy Creek.

Coal has been reported from Camas Mountain, T. 29 S., R. 8 W., in Douglas County. An analysis of this coal is numbered 31 in the table of analyses.[1] The bed of coal represented by the sample analyzed is reported to be 3 feet thick. It yields red ash and does not coke.

Coal has been found on Smith River in Douglas County, and on several streams which flow into the sea in Lane and Benton counties.

Two years ago Mr. G. J. Callahan opened a seam of coal in sec. 15, T. 27 S., R. 7 W., at the eastern foot of the Coast Range in Douglas County, and obtained from it about 9 tons. Some of the coal was used in a small engine and for blacksmithing, and it is said to have worked well. The seam is 9 inches thick and lies between layers of shale. Its analysis is No. 32 in the list. A calcareous bed overlying the shale a few feet contains numerous Eocene fossils, among which an oyster is quite common.

Of the localities for coal in Douglas County, those on the North Fork of the Umpqua, about 20 miles northeast of Roseburg, are perhaps more widely known than any others. This was made known as early as 1872 by Hugh Small, in his pamphlet on Oregon and Her Resources. The best outcrops are said to be from 2 to 4 miles above Hughes Ferry, and were not visited by the writer. Close to the Ferry and at several points on the East Fork, or Little River, as it is sometimes called, traces of coal are found, but there are no beds of economic importance. At one point on Cavitts Creek, half a mile above its mouth, two small beds of impure coal occur, one 14 inches and the other 3 inches thick. This outcrop was leased for several years to a blacksmith of Myrtle Creek, who is said to have mined several tons for use in his smithy. Analysis No. 33 shows the composition of the coal at this locality.

Good blacksmithing coal has been reported about the headwaters of the Coos River, and in the Coast Range of Yamhill County, as well as at many other points upon both sides of the Willamette Valley. A 4-foot bed, in horizontal sandstone containing leaf impressions, has been noted in Clackamas County, near Wilhoit Springs. Similar outcrops occur at many places along the western foot of the Cascade Range.

In the John Day Valley of eastern Oregon coking coal has been

[1] Tenth Census, Vol. XV, 1880, pp. 788-789.

found which yielded the analysis No. 34 of the table. Coal is said to occur also at Pendleton, but so far as yet known the great majority of the outcrops east of the Coast Range, excepting perhaps those of the upper Nehalem basin, are of little commercial importance.

Concerning the age of the coal-bearing strata of western Oregon, it may be stated that at Pebble Creek (Columbia County), Cape Arago (Coos County), Callahans, and North Fork of the Umpqua (Douglas County) they are definitely known to be of Eocene age; in the Lower Nehalem (Clatsop County) and Yaqnina (Lincoln County) coal fields they underlie a considerable thickness of fossiliferous Miocene strata and may be Eocene; at Coos Bay they are so related to both Miocene and Eocene strata that it is not possible without further examination to tell definitely to which they belong, but the tendency of the evidence suggests that they are Eocene.

Chemical analyses of Oregon coals.

No.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Physical properties of coke.	Analyst.
1	2.56	46.29	48.49	2.74	......	......	(?)
2	11.16	42.82	41.64	[1] 4.38	4.32	Sooty, incoherent.	Peter Fireman.
3	10.83	41.05	43.17	[1] 4.95	2.47	Partly brilliant and coherent.	Do.
4	10.03	43.40	29.98	[2] 16.59	3.69	Sooty, noncoherent.	Do.
5	12.23	42.47	34.29	[1] 11.01	3.19	.....do	Do.
6	10.07	44.52	32.18	[1] 13.23	3.97	.....do	Do.
7	9.75	32.25	50.50	7.50	......	......	......
8	9.53	42.73	42.29	5.45	......	......	J. H. Fisk and W. H. Hampton.
9	9.00	37.83	45.17	8.00	......	......	Do.
10	19.75	33.20	42.59	4.73	......	......	......
11	8.08	41.26	46.81	[1] 3.85	1.30	Partly brilliant and coherent.	Peter Fireman.
12	8.86	40.06	46.79	[1] 4.29	1.31	Partly brilliant and coherent.	Do.
13	8.91	41.54	47.23	[1] 2.32	0.38	Sooty, slightly coherent.	Do.
14	8.11	41.15	33.59	[1] 17.15	0.95	Sooty, noncoherent.	Do.
15	8.53	39.95	45.79	[1] 5.73	2.00	Partly brilliant and coherent.	Do.
16	15.50	31.40	39.80	13.30	......	......	Sharpless and Winchell.
17	9.12	43.86	42.73	[3] 4.29	0.46	Slightly coherent	Peter Fireman.
18	9.77	43.20	34.22	12.81	2.32	......	Sharpless and Winchell.

[1] Red. [2] Brown. [3] Light brown.

Chemical analyses of Oregon coals—Continued.

No.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Physical properties of coke.	Analyst.
19	10.81	46.52	34.26	8.41	....	....	Sharpless and Winchell.
20	12.26	43.16	33.93	10.65	....	....	Do.
21	4.97	42.13	44.91	7.99	1.22	....	Do.
22	5.33	48.31	38.78	9.58	....	....	Do.
23	4.05	46.51	38.15	11.29	....	....	Do.
24	10.42	42.21	43.18	[1]4.19	0.69	Sooty, very slightly coherent.	Peter Fireman.
25	9.78	42.57	44.19	[1]3.46	0.91	Sooty, partly coherent.	J. H. Fisk and W. H. Hampton.
26	11.94	41.48	37.85	[2]8.73	1.32	Sooty, noncoherent.	Do.
27	15.45	41.55	34.95	8.05	2.55	Will not coke....	Thomas Price.
28	17.27	44.15	32.40	6.18	1.37	.....do	Do.
29	11.00	41.00	44.50	3.00	0.45	....	J. A. Fisk and W. H. Hampton.
30	20.09	32.59	41.98	5.34	....	....	Do.
31	1.53	42.82	44.94	10.71	[1]4.49	Does not coke...	F. A. Gooch.
32	1.96	43.68	51.11	[3]3.25	1.66	Partly brilliant and coherent.	Peter Fireman.
33	4.66	38.54	39.00	[4]17.80	0.44	.....do	Do.
34	1.08	24.40	34.71	39.81	0.91	Worthless.......	F. A. Gooch.

[1] Light brown. [2] Red. [3] Brown. [4] Light yellow.

Localities of coals given in foregoing table of analyses.

1. Astoria. Mineral Resources of the United States, 1882, p. 94.

Upper Nehalem coal field, Columbia County:

2. Pebble Creek. Sec. 34, T. 4 N., R. 4 W.
3. Pebble Creek. Sec. 34, T. 4 N., R. 4 W.
4. East Fork of Pebble Creek. Face at interior end of tunnel of Great Northern Coal Company.
5. East Fork of Pebble Creek. S. W. ¼ sec. 23, T. 4 N., R. 4 W. At bottom of canyon.
6. East Fork of Pebble Creek. NW. ¼ sec. 23, T. 4 N., R. 4 W. At bottom of side ravine.
7. East Fork of Pebble Creek. Face of tunnel of Great Northern Coal Company's mine. Published by the company.
8. East Fork of Pebble Creek. Face of tunnel of Great Northern Coal Company's mine. Published by the company.
9. Nehalem No. 1. Location? Published by Great Northern Coal Company.
10. Nehalem No. 2. Location? Published by Great Northern Coal Company.

Lower Nehalem coal field, Clatsop County:

11. Hodge Creek. Sec. 16, T. 3 N., R. 10 W.
12. Hodge Creek. Sec. 16, T. 3 N., R. 10 W.
13. Coal Creek. SW. ¼ sec. 36, T. 4 N., R. 10 W.

Yaquina coal field, Lincoln County:

14. Shaw Place, $1\frac{1}{2}$ miles west of Toledo. Sec. 13, T. 11 S., R. 11 W.
15. Four miles northwest of Toledo. Sec. 30, T. 10 S., R. 10 W.
16. Yaquina Bay. Noted by Sharpless and Winchell.

Coos coal field, Coos County:

17. Riverton coal (Timon's mine).
18. Kight's mine, near Riverton; top.
19. Kight's mine, near Riverton; middle.
20. Kight's mine, near Riverton; bottom.
21. Coquille. Sec. 23, T. 27 S., R. 14 W.; average.
22. Coquille. Sec. 23, T. 27 S., R. 14 W.; above parting.
23. Coquille. Sec. 23, T. 27 S., R. 14 W.; below parting.
24. Beaver Hill mine. Sec. 17, T. 27 S., R. 13 W.
25. Newport mine. Sec. 9, T. 26 S., R. 12 W. Shows distinct woody structure; thrown out by picker.
26. Newport mine Sec. 9, T. 26 S., R. 12 W. Selected by superintendent.
27. Newport mine, Upper Beach. Sec. 9, T. 26 S., R. 12 W. Mineral Resources of the United States, 1887, p. 289.
28. Newport mine, Lower Beach. Sec. 9, T. 26 S., R. 12 W. Mineral Resources of the United States, 1887, p. 289.
29. Durham. Published by Great Northern Coal Company, of Portland.
30. Coos Bay. Exact location not known. Published by Great Northern Coal Company, of Portland.
31. Camas Mountain, Douglas County. Tenth Census, Vol. XV, p. 788.
32. Callahans, 11 miles west of Roseburg, Douglas County.
33. Near mouth of Cavitts Creek, Douglas County.
34. Blue Mountains. Tenth Census, Vol. XV, p. 788.

HINDRANCES TO THE DEVELOPMENT OF THE COAL FIELDS OF OREGON.

The coal fields of the Coast Range are covered by a growth of vegetation so dense as to greatly interfere with the coal prospector. A luxuriant undergrowth of vines and shrubs amid large numbers of fallen trees in the forests, especially in the ravines, where abundant moisture lingers throughout the summer, completely covers the slopes. The soft sandstone and shales readily crumble to soil, and thus contribute to the more complete covering of the underlying strata. The coal-bearing strata are all soft, like the coal itself, and crop out at the surface only along the lines of most rapid erosion—that is, along streams. In the gulches and ravines of small streams, where the force of the water in floods is not sufficient to sweep away the mass of logs and other rubbish, the outcrops are very few and prospecting is especially tedious; but along the larger streams, as, for example, the Nehalem, which, during freshets sweeps its bed, the rocks are well exposed.

The longer axes of the coal fields are more or less nearly parallel with the trend of the Coast Range, upon whose flanks they occur, and it would be expected that the streams descending from the range across the fields would give fine exposures, but the streams are generally so small that they afford meager outcrops.

While the dense floral covering, by obscuring outcrops, hinders the prospecting of the coal fields, after the mines are once opened the presence of abundant timber is an advantage in supplying the demands of the work.

The greatest hindrance to the development of the Oregon coal fields is the lack of transportation. All the navigable rivers and bays of the Oregon coast are obstructed by bars, which greatly interfere with navigation. Formerly the depth of low water on the bar in front of Coos Bay varied in different seasons, with the shifting bar, from 9 to 13 or 14 feet. Since the jetties have been built, the channel has been improved. In the four years 1881–1885 the number of vessels crossing the bar was 1,118, of which 98 drew more than 13 feet of water. The entrance to Coos Bay is regarded as one of the best along the Oregon coast, the obstacles interposed to navigation by bars at other unimproved places being great.

In the case of the Upper Nehalem coal field, however, development is not hindered by marine obstruction, but by lack of proper facilities for land transportation. Although the coal field is less than 30 miles from Portland, there is a divide between, which, taken in connection with the stream canyons and dense forest, presents considerable difficulty in the way of railroad construction; and until railroad facilities are provided the Upper Nehalem coal field must remain undeveloped.

THE COAL INDUSTRY OF OREGON.

Historical notes.—The only coal of Oregon noted by Prof. James D. Dana in 1841[1] was thin seams in the shale near Astoria. He refers to the coal in the Cowlitz, and reports that "coal is said to occur on the coast north of Oregon and on Vancouver Island." Fourteen years later Prof. J. S. Newberry wrote:[2]

> Although the fact has been frequently announced in the journals, no true coal had been found in California or Oregon at the date of our arrival in San Francisco [May 30, 1855]. About the time of our arrival in San Francisco, however, the carbonaceous deposits on the shores of Coos Bay began to attract the attention of the public, and it was confidently believed that there had at last been found beds of bituminous coal equal in quality to that imported from the Eastern States.

Professor Newberry did not visit Coos Bay, but he saw several cargoes of coal at San Francisco and Portland, and from the information furnished by others he reports as follows:

> This coal is interstratified with sandstones and shales, which form a series several hundred feet in thickness, the strata being very much disturbed by intrusion of trap rock, some of them being inclined at an angle of 45°. The beds of coal are found in the upper part of the series, being most fully developed on the shores of the bay, where the strata are much less disturbed than nearer Cape Arago. * * * Several of the strata associated with the coal are highly fossiliferous, most of the fossils being marine molusca.

From the above statement by Professor Newberry, it is evident that coal was mined at Coos Bay and reached San Francisco as early as 1855. From that time to the present there has been at least one mine in continuous operation. It is interesting to note that in the early report of Professor Newberry the highly inclined beds of Cape Arago

[1] U. S. Exploring Expedition under Commodore Wilkes. Geology, by J. D. Dana. Vol. X, p. 658.

[2] Reports of Explorations and Surveys for a Railroad from the Mississippi River to the Pacific, Vol. VI, Part II, p. 62.

were distinguished from the more gently inclined beds on the borders of Coos Bay.

More detailed information concerning the coal is furnished by R. W. Raymond, who, in 1870, wrote[1] as follows:

The Coos Bay coal deposit was examined during the year by Mr. William Ashburner, of San Francisco. It is composed of three seams, inclosed in sandstone, dipping toward the northwest at an angle of about 15°. The two principal and lowest seams are each 2 feet 3 inches in thickness, of uniform quality, and separated by an intercalated stratum of sandstone 4 inches thick. The upper seam of coal, being of inferior quality and only 1 foot thick, is not removed by the miners.

Mr. Hugh Small, in 1872, claimed[2] that the Coos Bay mines gave "employment to a regular fleet of schooners that trade to San Francisco and other ports, 60,000 tons being shipped from her mines last year." This large amount indicates considerable activity, and about that time there was great impetus given to coal prospecting in that region; but in 1876, according to Mr. Goodyear,[3] the Eastport and Newport mines were the only ones that had been successfully worked in the Coos Bay region, and of these only the Newport mine has survived.

The following table shows the annual production from 1880 to 1895. These figures are compiled from the volumes of Mineral Resources of the United States, published annually by the United States Geological Survey.

Coal industry in Oregon from 1880 to 1895.

Year.	Number of mines.	Total product in short tons.	Value.	Average price per ton.	Number of days active.	Number of men employed.
1880	......	30,000	....	....	....	....
1881	......	30,000	....	....	....	....
1882	......	30,000	....	....	....	....
1883	......	50,000	....	....	....	....
1884	......	50,000	....	....	....	....
1885	......	44,643	....	....	....	....
1886	......	45,000	$112,500	....	....	....
1887	2	31,696	70,000	$2.75	210	105
1888	2	75,000	225,000	3.00	245	160
1889	2	64,359	163,650	2.60	....	160
1890	1	61,514	177,875	2.89	....	208
1891	1	51,826	155,478	3.00	....	....
1892	1	34,661	148,546	4.29	120	90
1893	1	41,683	164,500	3.57	192	110
1894	1	47,521	183,914	....	243	88
1895	4	73,685	247,901	3.36	69	[4]414

[1] Mining Statistics West of the Rocky Mountains for 1870, p. 219.

[2] Oregon and Her Resources, 1872.

[3] Coal Mines of the Western Coast, 1877.

[4] The apparently large number of men employed and small average working time is due to the large force of men employed in developing the Beaver Hill mine, which was producing coal for shipment during only 20 days in 1895. The average time made at the Newport mine was over 200 days per man.

It has been stated[1] that the Coos Bay coal commands a better price in San Francisco than any other found on the Pacific Coast, and on the other hand,[2] that it "sells in San Francisco about $2 less per ton than Puget Sound coal of corresponding grade." There is also difference of opinion as to the use for which the coal is best adapted, whether for domestic or for steam-producing purposes. Mr. J. W. Harrison, of San Francisco, informs me by letter, dated December 20, 1895, that the Coos Bay coal is sold "entirely for house uses; being a lignite, it is not sooty, hence is preferred by housekeepers on account of its cleanliness. It is sold in San Francisco at fully 75 cents to $1 per ton less than Australian coal, at $1.25 to $1.50 per ton less than British Columbian coal, and 50 cents per ton less than Seattle coal."

IRON ORES.

The most interesting deposit of iron ore yet discovered in the State. and the only one that has been worked to a considerable extent, is that formerly operated by the Oregon Iron and Steel Company, near Oswego. and about 8 miles south of Portland. The ore is limonite, and lies between sheets of basalt dipping northwest at an angle varying from 20° to 30°. The following section (fig. 17) illustrates the mode of its occurrence. For many of the facts revealed along the drifts and tunnels of this mine I am indebted to Mr. William A. Pomeroy, who resides at the mine. The quotations are from a letter dated February 19, 1896:

The deposit is in the form of a bed, about 1 mile long and half a mile wide. The strike (nearly parallel with the greatest extent of the ore) is about E. 15° N., and the dip a little west of north. From the surface down the slope for 200 to 400 feet the dip is about 20° to 30°, but diminishes to an average of 8° to 10°. The ore is low-grade limonite or bog ore. It varies somewhat in hardness, color, and composition, owing to the varying amounts of silica and organic matter. The range of analyses is about as follows:

Composition of iron ore from near Oswego, Oreg.

	Per cent.
Metallic iron	30 – 40
Silica	7 – 15
Magnesia	2 – 3
Manganese	1 – 8
Lime	2 – 4
Phosphorus	0.37– 0.67
Sulphur	0.3 – 1

[1] Statistics of the State of Oregon, by A. J. Dufurs, 1869, p. 101.

[2] Resources of the State of Oregon, collected and prepared by the State Board of Agriculture. Minerals, by Herbert Long, p. 22.

From the southwest part of the outcrop down the dip 800 feet, the ore averages 38 to 45 per cent of metallic iron, contains more alumina, less silica, and is soft and friable. Going east on the outcrop about 1,500 feet, a hard, blackish, flinty, highly siliceous ore is found. It continues down on the dip about 200 feet and is 200 to 300 feet in length. Although there is always more or less of it through the bed in streaks, in some places the whole becomes almost oolitic in appearance, and in those places it is richest. The ore ranges in thickness from 2 to 20 feet, averaging 5 or 6 feet, with the irregular depressions and elevations of the lava surface on which it was deposited.

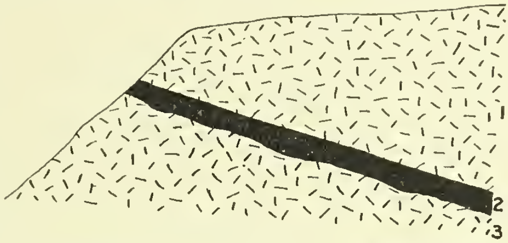


FIG. 17—Section at the Prosser mine. 1, Basalt; 2, Iron-ore bed; 3, Basalt.

As seen by the writer, the bed along the surface ranges from 2 to 8 feet in thickness, and it was traced for about a mile along the strike. The ore seen was generally brown, but varied from black to red. In some cases the red was associated with very siliceous material, reminding one very much of the red jasper found with some of the Lake Superior ores. The following analyses, published in the report of the Tenth Census (Vol. XV, p. 497), shows a somewhat higher percentage of iron than that reported by Mr. Pomeroy:

Percentages of iron and phosphorus in ore from near Oswego, Oreg.

	1165.	1167.	1166.
Metallic iron	44.71	54.19	45.40
Phosphorus	0.666	0.392	0.576
Phosphorus in 100 parts of iron	1.490	0.723	1.269

Specimen 1165 was taken from a pile of 150 tons of ore from the stock house at the furnace. Specimen 1167 was selected chippings of the crystallized ore.

The underlying lava, on whose irregular surface the ore was deposited, is dark-gray basalt, and usually very vesicular, showing that at the time of its extrusion it flowed out upon the surface. It is considerably decomposed in places, and by the process of decomposition oxide of iron is liberated. This fact points to the adjacent lava slopes that surrounded the small lake or swamp in which the ore was deposited as the original source of the iron. By surface streams or chalybeate springs the iron was brought to the lake or swamp, where, under the influence of organic, chemical, or mechanical agents, it was precipitated and accumulated to form the bed of ore.

At some points in the upper part of the ore bed logs are found, but they are most abundant in the sand rock in places immediately overlying the ore. Mr. Pomeroy collected some fossil leaves for me. He writes:

So far fossils have been found only in the roof, none occurring in the bottom of the bed. At this western part of the bed there is 8 to 14 inches of loose sand rock between the ore body and the hanging. This is found at the outcrop and continues for several hundred feet. The fossils are mostly in this sand rock, which is soft and easily friable, and presents more or less cleavage, some few isolated pieces of wood being found in the ore body itself, but always more or less completely silicified, and near the top. The trees in place have their roots in the sand rock, which is in some places 2 and 3 feet thick. The fallen trees, those in horizontal position, are found with a part of the trunk in the ore and sand rock and part in the hanging. Some of these trees are almost perfect, showing bark and apparently no decay. These trees vary all the way from 5 and 6 inches to 3, 4, 5, and even 6 feet in diameter. They are not found until you go down on the dip about 700 feet, and then they become quite thick, and can be traced east and west almost in a straight line for some distance, evidently showing an old water line.

The fossil leaves in the dark, hard rock came from this locality; those in the lighter, softer rock came from farther up the slope, about 300 to 450 feet from the mouth of tunnel.

After the ore was deposited with the locally overlying bed of sand, and the great forest trees, requiring perhaps centuries for their growth, had developed, the whole accumulation was covered up by another deluge of lava. The lava from this eruption is much more compact and its contact surface much more even than that of the lava below the ore. In type, however, the two rocks are the same, but the eruptions must have been separated by a considerable interval, during which the bed of ore was formed. At that time the upper surface of the ore deposit must have been horizontal, and after the eruption of the lava that covers the deposit, or perhaps in connection with it, the beds were so disturbed as to be tilted at an angle of 20° to 30°. The date of this disturbance has not been fixed, but it certainly belongs to a late geological period. Professor Pumpelly regarded it as probably Tertiary, and states that "similar ores are forming to-day in the great marshes, from the chalybeate waters drained from the decomposing basalts of the Cascade Range."

In order to determine, if possible, the age of the deposit, the fossil leaves collected by Mr. Pomeroy were submitted to Mr. F. H. Knowlton, of the National Museum, for determination. In the small collection he could recognize only a few leaves, which, he says—

appear to represent a single species of narrow, thick-leaved oak. This is almost the same as *Quercus elænoides* Lx., but differs in having a rounded instead of an obscure acuminate apex. The determination of the age on such imperfect data is obviously unsafe. The specimen of Quercus mentioned above is from the Miocene of California, and the Prosser mine specimens are so close to it, if not indeed identical with it, that it is at most an indication that they may also belong to the Miocene. But more and better material will be necessary before this can be settled definitely.

The ore of the Prosser mine was used in 1865[1] by the Oregon Iron Company in a furnace at Oswego, about 2½ miles from that mine. The

[1] Mr. J. Ross Browne (Report to the Secretary of the Treasury on the Mineral Resources of the States and Territories west of the Rocky Mountains, 1868), in considering the mineral resources of Oregon, quotes largely from the Oregonian, whose files afford so full a record of the development of the various industries within the State.

mine consists in general of three slightly converging inclines, running down the slope of the bed for nearly a thousand feet, and some of the ore has been taken out upon both sides. The capacity of the mine in 1880 was estimated at 20,000 tons a year. During that year it worked only three and two-thirds months, and yielded 6,225 tons. In June, 1895, the mine was not in operation.

Mr. Pomeroy says:

On the south side, and near the east end of Tualitin Lake, is a deposit of iron ore almost identical with the Prosser ore bed, known as the Patton bed, the dip, strike, foot, and hanging, and ore being almost the same, but it is quite limited in extent. In an air line the two deposits are from 1½ to 2 miles apart, the deep, narrow lake and swamps intervening.

There is a third, though very small quantity, about 50 feet or more lower in elevation and just east of the Prosser bed, about one-half mile from its east end, where it terminates abruptly against a basaltic ridge or cliff 100 to 150 feet in height. This bed has the same strike, but dips south toward the lake. The ore is very similar to the Prosser ore.

An analysis of ore from one of these localities, taken from the Tenth Census, is given in the last table, column 1167.

Limonite is a widely distributed ore of iron in western Oregon, and is generally associated more or less directly with igneous rocks. The soil of basalts nearly everywhere is full of small, earthy, shot-like concretions, composed of limonite, and their presence in the soil may always be taken as evidence of its derivation from a rock rich in iron.

On the North Fork of the Scappoose, about 25 miles northwest of Portland, a deposit of limonite occurs at the Raffety and Payne mine, from which about 400 tons of ore is said to have been removed. Its outcrop is upon a sharp spur in a short turn of the stream, at an elevation of about 450 feet above the sea, and nearly 300 feet above the stream. There has been no underground work, and the deposit is not well exposed at the opening. It lies between very much decomposed eruptive rocks. Near by, the eruptives are less altered and retain the vesicular character and crystalline structure which clearly indicate their igneous origin. The ore is said to have been traced along a very steep bluff upstream for nearly one-half mile. Mr. Herbert Lang reports[1] the following analysis of the ore at this locality:

Analysis of iron ore from the Raffety and Payne mine, on the North Fork of the Scappoose.

	Per cent.
Silica	1.25
Alumina	5.27
Sulphuric acid	3.22
Phosphoric acid	0.34
Water	15.54
Sesquioxide of iron	74.46
Total	100.08

[1] The Resources of the State of Oregon, compiled and prepared by the State Board of Agriculture, 1892, p. 26.

We were informed of an iron mine near Mr. West's, on the road from Greenville to Manning, but upon examination found only a ditch with a small quantity of limonite close to a rotten igneous rock. The rock is in general so thoroughly decomposed as to be recognized with difficulty, although in some places its original vesicular structure is still preserved. Mr. West said that some of the ore had been taken to Oregon City and pronounced good. This may well be, but the quantity of ore present appears to be small.

Farther up the West Fork of Dairy Creek, near Manning's, limonite occurs at several localities. At sec. 16, T. 2 N., R. 4 W., a short distance west of Mr. Manning's, there is considerable limonite, like that at Scappoose and Oswego. It is not so clearly associated with eruptive rocks as at Oswego, although basalts, both fresh and altered, occur in that vicinity. Only small pits have been dug in prospecting for the ore. While it is evident that the body of the ore present at this place is not large, it is equally apparent that under favorable circumstances, which do not now exist in that region, it would be worthy of attention. Similar masses of bog ore occur in a swampy tract a short distance southeast of Manning's, and at many points through the country, wherever circumstances were favorable, the oxide of iron resulting from the decomposition of the eruptive rocks accumulated to form deposits of limonite. Fine samples of limonite were seen at the hotel in Vernonia, and several miles southeast of that town is a ferruginous sandstone; but these were not seen in place. Such ore occurs at a number of points in the Coast Range, but all the localities at which it has ever been mined, as far as known to the writer, have been mentioned.

An entirely different class of iron ore occurs among the older rocks of the Klamath Mountains, in the southern part of the State. Mr. Corning, of Corvallis, gave me a fine specimen of magnetite, from Josephine County, in the southern part of the State. Its composition has not been determined. If this ore occurs in abundance at the locality indicated, it will doubtless be of importance some day as a source of iron ore.

Oregon produced a small amount of pig iron in 1894, but reported no iron ore mined.

In 1880 Oregon was seventeenth among 23 iron-producing States.

In 1889 Oregon was nineteenth among 28 iron-producing States.

In 1893 Oregon was twentieth among 25 iron-producing States.

SANDSTONE.

The rocks of the Coast Range of Oregon are chiefly sandstones, shales, and basalts. Although widely distributed, they are not all of economic importance. The shales are of but little use. The calcareous nodules they contain, in some places abundantly, have been burned to lime, but the amount is very limited.

The sandstones are quarried in many places for building purposes. Those near the coast are generally soft, and are used chiefly in the construction of jetties. At Tillamook Bay and Coos Bay they are quarried for this purpose within easy reach of tide water.

The principal sandstone quarry of western Oregon is the one at Pioneer, on the Yaquina River, in Lincoln County. At that place the sandstone occurs in massive beds and affords an excellent building stone. Being soft, it is easily shaped, and yet is durable, with a good, gray color. The heavy beds allow it to be quarried in large pieces, in some cases 10 feet thick. It is carried by railroad from the quarry to tide water, and then towed on barges down the bay. The rock dips gently, and a great mass of it is exposed, so that it will furnish material for some time to come. During 1895 there were many tons of rock shipped from this quarry, and nearly all of it went to San Francisco.

About 5 miles south of Forest Grove, in Washington County, at Boose's quarry, a solid dark-gray sandstone is quarried for building purposes, and is quite extensively used in the surrounding country. The rock contains numerous Miocene fossils.

At several points a few miles south of Corvallis, and at Monroe, still farther south, in Benton County, considerable sandstone has been quarried, but for local use only.

About 2 miles from Jefferson, Marion County, a sandstone has been quarried and used by Mr. F. Wood, of Albany, in the construction of monuments. It is of dark-gray color, easily cut, and occasionally shows upon a fresh fracture irregular areas of bright reflections from the calcareous cement which holds the sand together. The rock, being fine-grained, receives delicate carvings, and was used for the ornamental memorial stone from Oregon in the Washington Monument at the national capital. Small cubes of this sandstone are said to have been tested, and found not only to have a high crushing strength, but to stand fire well. This would be expected from the nature of the sand, which is made up largely of volcanic material. Characteristic fossils occur in this region as well as near Corvallis, showing that the sandstone belongs to the Eocene formation, and may be older than the sandstone at Pioneer and the Coast Range farther northward.

Sandstones are especially abundant in the Coast Range south of the latitude of Eugene City, and are well exposed along the Umpqua and Coos rivers and the forks of the Coquille. A great bluff of sandstone forms the eastern escarpment of the range from Tyee Mountain and Coles Valley to Camas. The same rock continues farther southward, lapping over the older strata, but in places it gets coarser grained, and, rising higher in the mountains, is less available. Along the coast, however, it is much more easily reached. Near Port Orford, and perhaps at other points south of the district embraced in this reconnaissance, the sandstones have been quarried for the San Francisco market.

LIMESTONE AND MARBLE.

It is well known from the publications of Mr. Herbert Lang that limestone, sometimes in the form of marble, occurs in a number of places in the Klamath Mountains of southwestern Oregon, as, for example, near Rocky Point, in Jackson County, and on Williams Creek, in Josephine County. Farther northward, on the borders of the Willamette Valley, in Marion and Polk counties, shell limestone is said to occur.

There is also an interesting occurrence of marble in Douglas County, less than a dozen miles southeast of Roseburg. The narrow belt in which the lenticular masses here and there crop out extend northeast from the Umpqua toward Peel for a distance of at least 20 miles. The outcrops best known are at Cooper's, Flint's, and Whitsett's, and at the quarry of the Variety Marble Company, of Roseburg. At the first two localities it has been burned for lime. At the last locality a mill was erected to saw the marble into slabs, and some of it has been used in Roseburg. The mill was not running in the summer of 1895. The marble is one of remarkable beauty, being handsomely variegated with red, yellow, gray, and white. Much of the rock is mottled gray, with a multitude of white veins, while other portions are brecciated with brilliant shades of red and yellow, veined with white and irregular areas of gray. The marble, when well polished, is one of the most beautiful variegated marbles of this country. It appears, however, that different portions of the mass vary considerably in hardness, rendering it somewhat difficult to work. Furthermore, the quantity exposed at the quarry is quite limited, although farther southward in the same belt larger lenticular masses are exposed.

BASALT.

Under this head are included the modern lavas so extensively used for road metal at many places. At Portland they form a portion of the heights, and they occur at many points throughout western Oregon. This rock forms the falls of the Willamette at Oregon City, and many of the hills throughout the great valley, the fertility of which is largely due to the rich soil furnished by the alteration and disintegration of the lavas.

It is well known that this rock stands among the very best materials obtainable for road construction. In large cities it is sometimes used in the form of paving blocks, but also in the form of fine stones for macadamizing. It is thus employed quite extensively in Portland.

One mile south of Dilley, in Washington County, in this sort of rock, is the county stone quarry for road metal. A crusher is located here, and the crushed stone is hauled a long way. The good roads of that region show the wisdom of such practice.

Basalt is one of the most solid and enduring rocks, but its hardness and tenacity render it comparatively difficult to trim. On account of its somber color it is little used for building, excepting for foundations, and for this purpose it has a wide application. It frequently possesses a columnar jointing that cuts it up into pieces too small for building stone. Occasionally columns are sufficiently regular to be used for fence posts without further trimming. This is especially the case along the Rhine, in Germany.

According to the official report[1] on the stone industry for 1894, granite is quarried in Jackson and Columbia counties; diabase in Linn County; basalt in Clackamas and Linn counties, and andesite in Multnomah County. The value of the granite quarried in Oregon in 1890 was $44,150; in 1891, $3,000; in 1892, $6,000; in 1893, $11,255; in 1894, $4,993. The rocks classed above as granite, diabase, basalt, and andesite are all of igneous origin. In the trade, names of rocks are frequently used without careful discrimination, and they may have to be changed when the rocks are studied.

GOLD.

In recent years the gold-mining industry of western Oregon has been steadily growing in importance. According to the report of the Director of the Mint, the counties west of the Cascade Range ranked as follows in the production of gold in 1894:

Josephine County	$123,676.61
Coos County	109,353.77
Jackson County	107,647.00
Douglas County	70,879.38
Lane County	32,500.00
Curry County	8,800.00
Linn County	5,000.00
Benton County	2,045.00
Marion County	985.00

The profitable production of gold in western Oregon is confined almost exclusively to the areas of the older rocks, such as those of the Klamath Mountains. They are the same as those of the Sierra Nevada of California, which have long been celebrated for their metallic wealth. None of the producing quartz mines lie within the region of this reconnaissance, although much was heard of them, and some fine specimens were seen from the mines in the southern part of Coos County and the eastern part of Lane County, where active mining operations are now being carried on.

Although the greatest production is in the Klamath Mountains, there is at present considerable activity at various points along the western slope of the Cascade Range, as, for example, in the Bohemian region, near the boundary between Lane and Douglas counties, as well as on the McKenzie Fork and at Quartzville, in Marion County.

In the northern portion of the Coast Range, near the borders of Clatsop and Columbia counties, there has been much prospecting, but

[1] Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. IV, pp. 444 and 461.

no productive mines have yet been worked. The Rock Creek mines, which are most easily reached from Vernonia, are located in altered, igneous rocks, closely related to basalt. They are probably of Eocene age, and belong to the mass which forms the core of the Coast Range from Saddle Mountain to Vineyard Hill, near Corvallis. They are considerably changed since their eruption, and while it is possible that they may contain metalliferous deposits of economic value, the presence of these is not yet certainly known.

On the North Fork of Myrtle Creek the placer mines are worked to a very limited extent. These are said to have once been the most extensive placer mines of southern Oregon, and are supposed to have produced upward of $80,000 annually. They lie within the area covered by the Roseburg sheet, and will soon be mapped in detail.

Among the most interesting of the mineral resources of the region embraced within this reconnaissance is the auriferous black sand near the coast. This is found chiefly in Coos County. These sands were carefully studied, over part of the area, in the spring of 1895, by Messrs. Sharpless and Winchell; their report is not yet published, but the writer has been permitted to consult it and quote from it.

Although the writer passed through the same region and visited some of the mines, he remained there only a short time, hoping to avail himself, as he now does, of the results obtained by the detailed observations of Messrs. Sharpless and Winchell. According to these observers, the auriferous black sands occur along the beach for some miles north of the mouth of the Coquille, and extend inland about 2 miles, attaining an altitude, along the eastern margin, of nearly 100 feet above the sea.

The deposits in question are beds of more or less stratified sand and gravel, in which are embedded many trunks and stumps of trees, some of great size, and species, such as redwood, known to exist only in California. The sand consists mainly of grayish-colored silica and feldspar. It also contains garnets, rubies, magnetite, ilmenite, chromite, and metallic gold, platinum, and iridosmine. The washing and blowing of the sand on the beach tends to concentrate the gravel and bowlders into certain strata, and the heavy minerals above-mentioned into others. It thus happens that the bowlders are mainly confined to the lower portion of these sand deposits, while the heavy sand, containing a relatively large percentage of black sand and of the precious metals mentioned, lies just above, in beds which vary in thickness from a few inches to 10 or 12 feet. On top of the black sand is a varying depth of gray sand; near the beach it will vary from 3 or 4 feet to 30 feet, while a mile away from the beach it will vary from 30 to 60 feet.

Gravel streaks occur all through the sand at irregular intervals, but the pebbles in the upper strata are seldom larger than 1 inch in diameter.

The bowlders are of many varieties, but siliceous rocks are most numerous, and those of petrified wood are frequent. It is worthy of note that many of these bowlders of silicified wood are partly or wholly black, indicating that they were partially lignitized before being silicified. Bowlders of porphyry, of diabase, and of other basic siliceous rocks are present, as are also fine greenish conglomerates.

The fine sand contains beautifully perfect crystals of garnet, ruby, and the iron minerals, besides some green mineral not determined.

The gold present in these sands is in the form of minute scales of native gold.

These yellow scales or flakes frequently assume the shape of small cups or basins, and are thus easily moved by flowing water or moving currents of air. Indeed, when exposed to the air and again immersed in water they will frequently float with persistency on the surface of the liquid, on account of the minute air bubbles which collect upon them. In processes of concentration, whether natural or artificial, they are thus gathered together with the iron minerals of considerably less density, but more compact and rounded form. It is due to this fact that the larger part of the gold is found in the black streaks and layers, while the gray sand contains scarcely any.

The size of these gold flakes or "colors" varies widely, some of them are so small as to be barely visible with the unaided eye, and others are one-sixteenth or even one-eighth of an inch in diameter. On account of their extreme tenuity the prospector is inclined to overestimate the value of the gold in the sand which he is prospecting with a pan. Thus, when from 20 to 30 colors are found in a pan, it is usually concluded that that sand is well worth working, and will run $2 or $3 to the cubic yard. This we found to be a mistaken estimate. As a matter of fact, the value of 600 colors is but 1 cent, and if 200 shovelfuls of 10 pounds each should each yield 30 colors, the value of the ton of sand thus treated would amount to but 10 cents. In this fact lies one fruitful source of disappointed hopes and unsuccessful enterprises in the working of auriferous black sands.

The pan is a convenient prospector's implement, but it gives merely a relative test, and should be checked by some absolute determinations, such as assaying or careful weighing of the colors obtained.

Messrs. Sharpless and Winchell examined many samples of sand, both gray and black, and they say:

Taking together all of the gray sands, we have 7.2 cents per ton as about the average value. It will be seen from this table that the amount of gold in the gray sand is extremely small—with but two possible exceptions, too small to treat the sands with profit for its recovery. The black sands, however, contain a sufficient quantity of gold to make their treatment a subject worthy of serious consideration.

The average value of ten samples of black sand given in the table referred to above is 55 cents per ton. Some of the samples were from the beach; others were from mines near the eastern limit of the black-sand area. The samples from the beach were much the richest in gold.

Of the valuable metals contained in the Oregon black sands, platinum is one of some importance. All records go to show that it has been found in greater or less quantity wherever gold has been found on the Pacific Coast. Of the samples taken by ourselves not one of those assayed yielded more than a trace of platinum, but samples from adjoining properties submitted to us for examination, samples that we have every reason to believe were honestly taken, yielded about two-tenths of an ounce per ton in the sand and 3.47 ounces per ton in the concentrates.

Platinum was found at three points by us when panning with the shovel, but, as noted above, only traces were found when the original samples were assayed.

The concentrates which were made while we were on the beach carried no platinum. Of several samples of concentrates made previous to our arrival, and later examined by us, only one carried an appreciable amount of platinum.

We therefore come to the conclusion that the platinum is not distributed in any uniform ratio with the gold through the sand, and can therefore not be depended upon as a constituent of value; at least its presence can not be depended upon so that profit may be calculated from it.

We believe beyond doubt, however, that at some point in the district under consideration the concentrates would show sufficient platinum to pay for its extraction if mining operations were in progress.

One sample of concentrates containing both gold and platinum was treated in the following manner: The concentrates were allowed to stand under a weak solution of potash twenty-four hours. Mercury was then added, and 92 per cent of the gold was amalgamated; the residue was treated with the magnet to remove magnetic iron, and subsequently concentrated again. The last concentrate was resmelted. The results showed that about 80 per cent of the platinum in the original concentrates was saved, about 10 per cent was carried with the magnetic iron, and about 10 per cent was washed away by water in the reconcentration. While this method is accompanied by a loss of 20 per cent of the metal, it is so simple that a concentrate carrying twenty-five one-hundredths of an ounce of platinum per ton can be treated with profit. A more complete extraction would be obtained by direct smelting or by amalgamating in an acid solution, but the accompanying cost would prohibit the treatment of any material carrying less than 1 ounce per ton.

Chemical examination of the black sands of California and Oregon has frequently shown the presence of small quantities of the metals iridium and osmium, in some cases occurring as iridosmium, and in others alloyed with platinum in varying proportions. Our examination failed to show any appreciable quantity of these metals, so we do not think that their presence can be relied upon as a source of profit. A sample of concentrates submitted by Mr. Smith from an adjoining claim showed over an ounce of iridosmium per ton. When working on an extensive scale, the concentrates would probably often show traces of these metals, and when present in very small quantities they would pay for extraction.

Iridium is quoted at about $15 per ounce, and osmium at $60 per ounce. These metals would be recovered with and in the same manner as the platinum.

Sharpless and Winchell considered the value of the ores of iron and chromite in the black sand, and also a possible use of the black sand in the manufacture of abrasives, but came to the conclusion that at present they are of little if any value to those working the black sands.

The auriferous black sands along the coasts of Oregon and California have been known for many years, and many attempts have been made to extract the gold, but it is so fine that nearly all efforts to save it have failed. Within the last few years a machine, known as the "Rossman concentrator," has been constructed and successfully used in the northern part of Curry County. The same apparatus was tested by Sharpless and Winchell with good results, and in their report they fully describe the machine as affording the most promising method known at present of recovering the valuable contents of the black sand.

In September, 1895, when the writer visited the Pioneer mine, on the road between Empire and Bandon, in Coos County, active preparations were being made to use the Rossman concentrator. The mine used to be known as the Lane mine, and is now operated by C. F. Allen, J. A. Rupert, and several associates. It is located near the head of a ravine about a mile and a half from the ocean, at an elevation of less than 100 feet. The layer of black sand is about 5 feet thick, and is usually richest near the bottom. An ordinary shovelful, panned upon the shovel itself, yielded about 10 colors. The sand at this point is evenly stratified and looks as if regularly water-laid. At the base of the black sand are occasional logs, in which the wood is well preserved. Mr. F. H. Knowlton has examined a specimen of the wood from one of these logs and pronounces it redwood, which at the present time is not known to grow north of the California line.

Three samples of the black sand were taken from the black-sand layer; one near the bottom, another near the middle, and a third near the top. The samples were small, and not intended for quantitative analyses, the chief aim being to get a general idea of its mineralogical composition, leaving a more detailed investigation until the maps of the region are completed. Although the black sand is generally composed of essentially the same minerals, they vary in relative abundance from place to place. It is remarkably beautiful when viewed under a microscope, owing to the great variety and brilliancy of the colors.

The sample from the basal portion of the layer in the Pioneer mine is composed chiefly of garnet, magnetite, ilmenite, and chromite, with a smaller amount of staurolite, zircon, epidote, and gold. In determining the mineralogical composition of the sand, it was first divided into two portions by means of a small hand magnet. Some of the magnetic material gave a strong reaction for titanium, so that ilmenite as well as magnetite is present.

The nonmagnetic portion of the sand still contained a large number of lustrous coal-black grains intermingled with pale purple and clear red grains, and a smaller proportion of reddish-yellow and colorless or pale yellowish and yellowish-green grains. Treated for a number of hours over a water bath with hydrofluoric and sulphuric acid, the purplish and clear red grains, as well as the yellowish-green ones, disappeared, but the others were not appreciably affected.

Under the microscope the purplish and clear red grains are found to be completely isotropic, indicating that they are isometric, and probably garnet, of which they have the luster and hardness. The purplish grains are usually angular; but of the red variety, rounded grains and well-defined trapezohedral crystals are most common. They look like rubies, but are distinguished by their form and chemical reactions. When fused with carbonate of soda and treated with nitric acid they yield a pink solution, due to the presence of manganese, hardly deep enough in color, however, to indicate spessartite. The purplish grains treated in the same way did not give a decided reaction for manganese.

The greenish-yellow grains, when crushed, are found to be pleochroic, from colorless to light yellow, and yield brilliant colors between crossed nicols, suggesting that the grains are epidote.

The acid reaction noted above removes the ilmenite and magnetite, but leaves a dark mineral which crystallizes in regular octahedrons with truncated edges. When crushed it is found to be brown in transmitted light, and with salts of phosphorus gives a strong reaction for chromium, showing that it is either picotite or chromite.

The colorless to pale yellowish mineral is generally in wheat-shaped grains, thick in the middle and tapering both ways, with ends well rounded by attrition, but occasionally the crystal terminations are well preserved. The mineral is infusible and doubly refracting, with parallel extinction. The crystals are generally in the form of square prisms with simple pyramidal terminations like zircon, but occasionally forms like that illustrated by Dana (Text-book of Mineralogy, 1877, p. 283), from McDowell County, N. C., appear.

The reddish-yellow grains are infusible, do not become magnetic, and have a specific gravity below 4. Between crossed nicols they yield brilliant colors, and are pleochroic, like staurolite, from honey to reddish yellow.

It is probable that there are other minerals in the sand, but in the small amount examined these were the only ones seen.

Gold is much less abundant than any of the other minerals already mentioned, but yet so plenty that a small shovelful yielded 30 to 50 minute colors. No platinum or iridosmine was seen. In searching for these minerals, 80 grams of sand was taken and reduced by fusion with potassium bisulphate and potassium fluoride, but no certain trace of either metal was found. This is not to be wondered at, when we consider the variability in the composition of the sand and the small amount treated.

An assay was made of the same material, but only a trace of gold was found, and no platinum.

The source of the black sand is to be found in the crystalline rocks of the Klamath Mountains, which, like those of the Sierra Nevada of California, part of the west slope of the Cascade Range, and the Blue Mountains of eastern Oregon, belong to the auriferous slate series. These rocks contain not only the gold, but the silver, nickel, platinum, and other rarer precious metals, besides a large portion of the iron ore, and on this account the Klamath Mountains and the Blue Mountains must be regarded as the most important sources of metalliferous wealth in the State of Oregon.

FURTHER CONTRIBUTIONS TO THE GEOLOGY OF THE SIERRA NEVADA

BY

HENRY W. TURNER

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FURTHER CONTRIBUTIONS TO THE GEOLOGY OF THE SIERRA NEVADA.

By Henry W. Turner.

CHAPTER I.

GENERAL REMARKS.

The following notes on the rocks of the Sierra Nevada may be considered as supplementary to a paper on the same subject published in the Fourteenth Annual Report of the United States Geological Survey. As was noted in the first paper, the writer's investigations cover two portions of the range, one portion being a strip 30 miles wide just south of the fortieth parallel, embracing the area covered by the Chico, Bidwell Bar, and Downieville atlas sheets, and the other lying chiefly to the south of the Cosumnes River, or approximately of latitude 38° 30′ north. The accompanying diagram (Pl. XVII) shows the disposition of the atlas sheets, under which headings the districts will be described. The sheets represented on Pl. XVII have not all been topographically mapped. The Dardanelles sheet may be finished in the season of 1896, but for the completion of the topographic work in the following areas no definite dates can be assigned, namely: Oakdale, Bridgeport, Mount Dana, Merced, Mariposa, Mount Humphreys, Bishop Creek, and Independence. The topographic mapping of the areas noted on Pl. XVII and not mentioned in this paragraph is finished and the maps are in print.

Mr. Waldemar Lindgren has acquired a large amount of information concerning the district across the central part of the range from Sacramento to Lake Tahoe, or between the two areas studied by the writer, and the geological maps of that section have been prepared by him or under his direction. His notes, when published, will add much to our knowledge of that portion of the range.

The writer is indebted to Prof. L. V. Pirsson and Prof. J. P. Iddings for friendly criticisms, and to the chemical division of the Geological Survey for accurate analyses, without which the petrographic part of this paper would have small value. All the photomicrographs illustrating the chapter on rock classification are from photographs taken by Prof. J. V. Lewis.

THE SIERRA NEVADA AS A WHOLE.

In a paper on the succession of the igneous rocks[1] the writer published a small geological map of the Sierra Nevada, which is produced herewith with slight additions and in colors (Pl. XVIII).

The Sierra Nevada as a topographic unit may be described, following Whitney,[2] as the mountain area lying to the east of the great valley ot California and to the west of the Great Basin, extending from near the Tejon Pass at the south end of the Great Valley to Lassen Peak on the north. As thus defined, the range lies wholly in the State of California, except the high granite spur just east of Lake Tahoe. Diller[3] has suggested, however, on geological grounds, that the range be limited on the north by the lavas of the Lassen Peak region, in the neighborhood of the North Fork of the Feather River, for to the north of this line there existed during Cretaceous time a great depression, which late in the Tertiary was filled in by the lava flows of Lassen Peak, which Diller considers as geologically related to the Cascade range.

A little to the west of the Tejon Pass, according to Whitney,[4] "we pass at once from undisturbed Tertiary to strata of the same age which are elevated at a high angle, and in so doing we leave the system of the Sierra and pass to that of the coast ranges." In a previous paper[5] the writer suggested that this line, separating little disturbed and highly disturbed beds, probably represented a line of faulting, the continuation of which farther north is apparently followed by the San Joaquin and Sacramento rivers. As is well known, the upper Cretaceous and Tertiary strata to the east of these rivers in the Sierra Nevada lie nearly horizontal, while to the west of it they are at nearly all points deformed. Adopting Diller's restriction of the range at its north end, the Sierra Nevada may be considered as terminating on the north a little to the north of the North Fork of the Feather River; on the east, at the west edge of the Great Basin; on the south, at the Mojave Desert, and on the west at the hypothetical line of faulting above indicated, and in the Great Valley at the San Joaquin and Sacramento rivers. The eastern part of the Tehachapi Mountains will thus fall in the Sierra Nevada system. The geologic map (Pl. XVIII) shows the range as thus restricted, the broken lines on the east and south being the line separating the Sierra Nevada from the Great Basin and the Mojave Desert. That portion of this line between Owen and Mono lakes and the portion east of Lake Tahoe coincide with a probable line of faulting, along which the Sierra has been elevated or the Great Basin depressed (or perhaps movements in both directions have occurred) in Tertiary time.

[1] Jour. of Geology, Vol. III, pp. 385-414.
[2] Auriferous Gravels of the Sierra Nevada, p. 7.
[3] Eighth Ann. Rept. U. S. Geol. Survey, p. 404, and Pl. XLV.
[4] Geology of California, Vol. I, p. 167.
[5] Am. Geologist, Vol. XIII, p. 248.

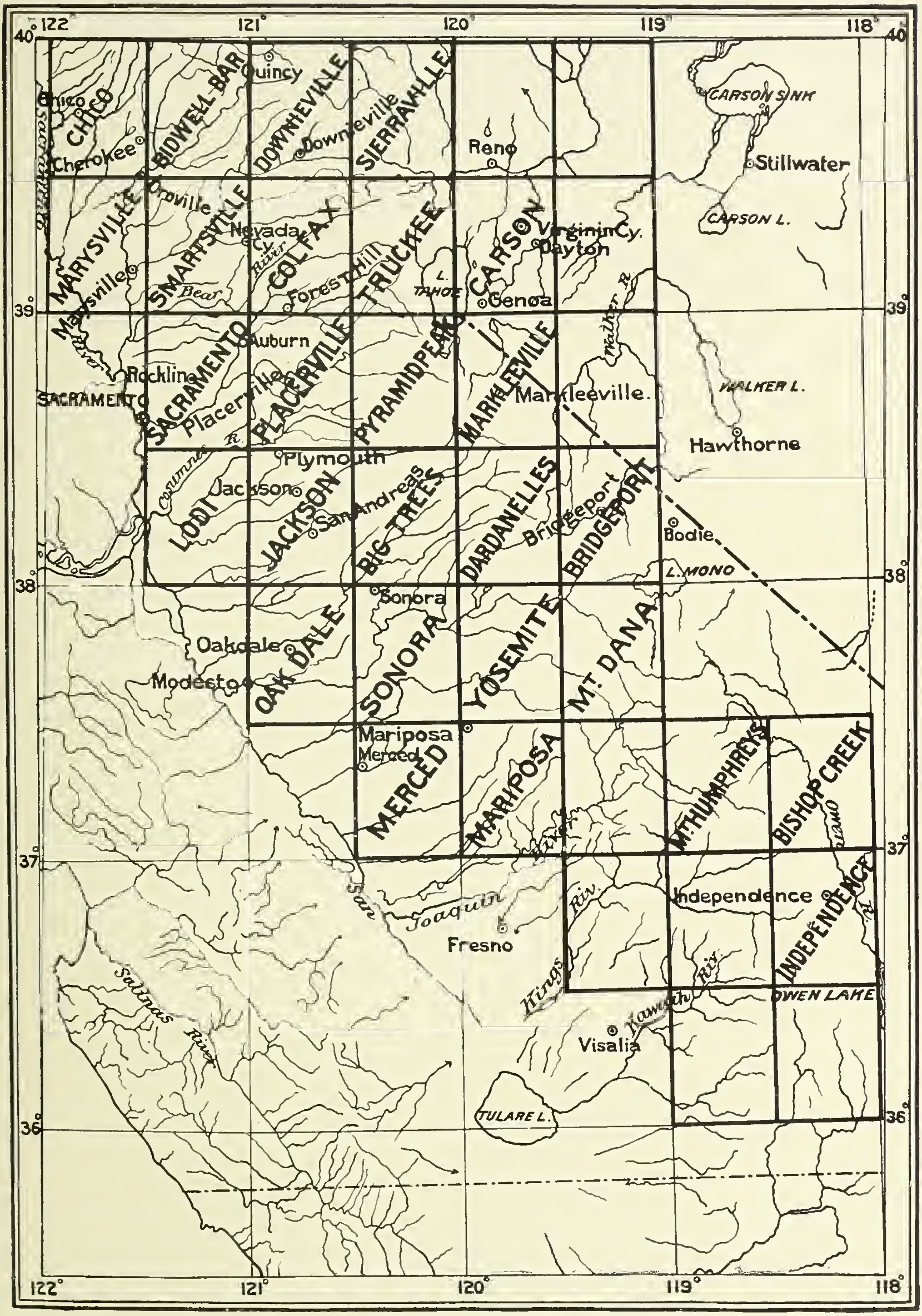


DIAGRAM SHOWING THE POSITION OF THE VARIOUS TOPOGRAPHIC SHEETS OF THE SIERRA NEVADA.

The Sierra Nevada, as thus outlined, appears to constitute a block of the earth's crust that has been quite rigid since middle Cretaceous time, although it has since, in common with most of California, experienced a considerable elevation, and there has been displacement by normal faults within the mass, particularly in Plumas County, at the north end of the range.

In another respect also the Sierra may be considered a geological unit. The Tertiary lavas throughout the mass that have the widest distribution are very similar at distant points and unlike Tertiary lavas in other adjacent areas, especially as to the form of their occurrence and their relation in time. Thus the oldest flows of large extent were of rhyolite, succeeded by hornblende-pyroxene-andesite, chiefly in the form of tuff and breccia. This relation does not appear to hold good in the Lassen Peak region, according to Diller, or in the Great Basin, according to King and Iddings. The sediments of which the Sierra Nevada are in part composed are presumed to have been derived chiefly from an Archean land mass lying west of the central part of the State of Nevada, although it is by no means impossible that an Archean land area once existed on the site of the present coast ranges, and in that case part of the sediments may have been derived from the west. It is probable that there are, within the Sierra Nevada, formations ranging in age from Archean or Algonkian to recent. Excepting, however, some Silurian fossils at the north end of the range, no evidence from fossils has thus far been found of rocks older than the Carboniferous, although in the northwest extension of the Auriferous slate series of the Sierra Nevada in Siskiyou and Shasta counties, Diller and Fairbanks have collected Devonian fossils. Evidence of the existence of Archean gneisses will be given in this paper. On the geologic map (Pl. XVIII) only the older formations, constituting the Auriferous slate series, with the associated igneous rocks, are represented. On this map the Paleozoic corresponds with the Calaveras formation of the Gold Belt maps; the two narrow belts of Juratrias on the west slope of the range are the Mariposa beds; the Juratrias beds northwest of Lake Tahoe are the Sailor Canyon and Milton series, and the area in the southern part of the Sierra at Mineral King is probably Triassic in age. Under granite, which forms much the larger part of the range, are included the quartz-mica-diorite or granodiorite of Becker and Lindgren and the porphyritic granite described in the Fourteenth Annual Report, as well as other types of granite Nearly all the small areas noted on the map inclosed in schists or in basic igneous rocks are granodiorite, the porphyritic granite occurring chiefly along the crest of the range, especially in its southern part. The magnesian series comprises serpentine, talc, and tremolite schists, with some other associated amphibolitic schists, the entire series being derived from basic igneous rocks. The porphyrites (old andesites) and amphibolitic rocks are chiefly altered forms of original surface lavas and tuffs corresponding to modern basalts and andesites.

THE AGE AND FORMATION OF THE SIERRA NEVADA.

Concerning the age and formation of the range, the author has practically nothing new to communicate, but for the sake of clearness the following is inserted:

The Sierra Nevada was formed at the close of the Jurassic (after the Mariposa beds were deposited) as a great mountain range, by the folding of the Paleozoic and Juratrias rocks of which it is composed, accompanied by the intrusion of vast amounts of granitoid rocks. During the Cretaceous this Jurassic mountain range was greatly eroded, so that portions of the range formed an approximation to a peneplain. In Tertiary time the zone of normal faulting along the east base of the Sierra, previously referred to, appears to have been formed. According to Clarence King, faulting may have begun along this line in Eocene time, but it is certain that later displacements have increased the height of portions of the fault scarp. He has shown that these two periods of organic movement—one, the earlier, characterized by folding, and another, later, by normal faulting—are to be recognized in the Great Basin. King writes:[1]

The geological province of the Great Basin, therefore, is one which has suffered two different types of dynamic action—one, in which the chief factor evidently was tangential compression, which resulted in contraction and plication, presumably in post-Jurassic time; the other of strictly vertical action, presumably within the Tertiary, in which there are few evidences or traces of tangential compression.

The two grandest fault lines shown in the Great Basin are those which define its east and west walls. Whoever has followed the eastern slope of the Sierra Nevada from the region of Honey Lake to Owen's Valley can not have failed to observe with wonder the 300 miles of abrupt wall which the Sierra Nevada turns to the east. That wall is no other than a great continuous fault by which the Nevada country has been dropped from 3,000 to 10,000 feet downward. In this low trough east of the Sierra Nevada and Cascade Range is laid down the thick series (amounting to 1,000 feet, as already described) of Miocene beds. It is therefore evident that this was a depression which was defined before the beginning of Miocene time. On the western base of the Sierra Nevada the marine Miocenes are found far down abutting against the extreme foothills of the range. As yet in the depressed area east of the Sierra Nevada no Eocene beds have been discovered, from which it seems highly probable that the great fault occurred either within the Eocene or at the close of Eocene time, and was the direct cause of the subsidence whose area was immediately occupied by the Miocene Pah-Ute lake.

Since the Sierra Nevada along its crest and eastern wall is chiefly formed of granitoid rocks, it is impossible to determine the amount of the drop which the downward movement has caused; for if, as is evident, the fault occurred before the Miocene, there has been the enormous erosion of all subsequent time to reduce the crest of the great range.[2]

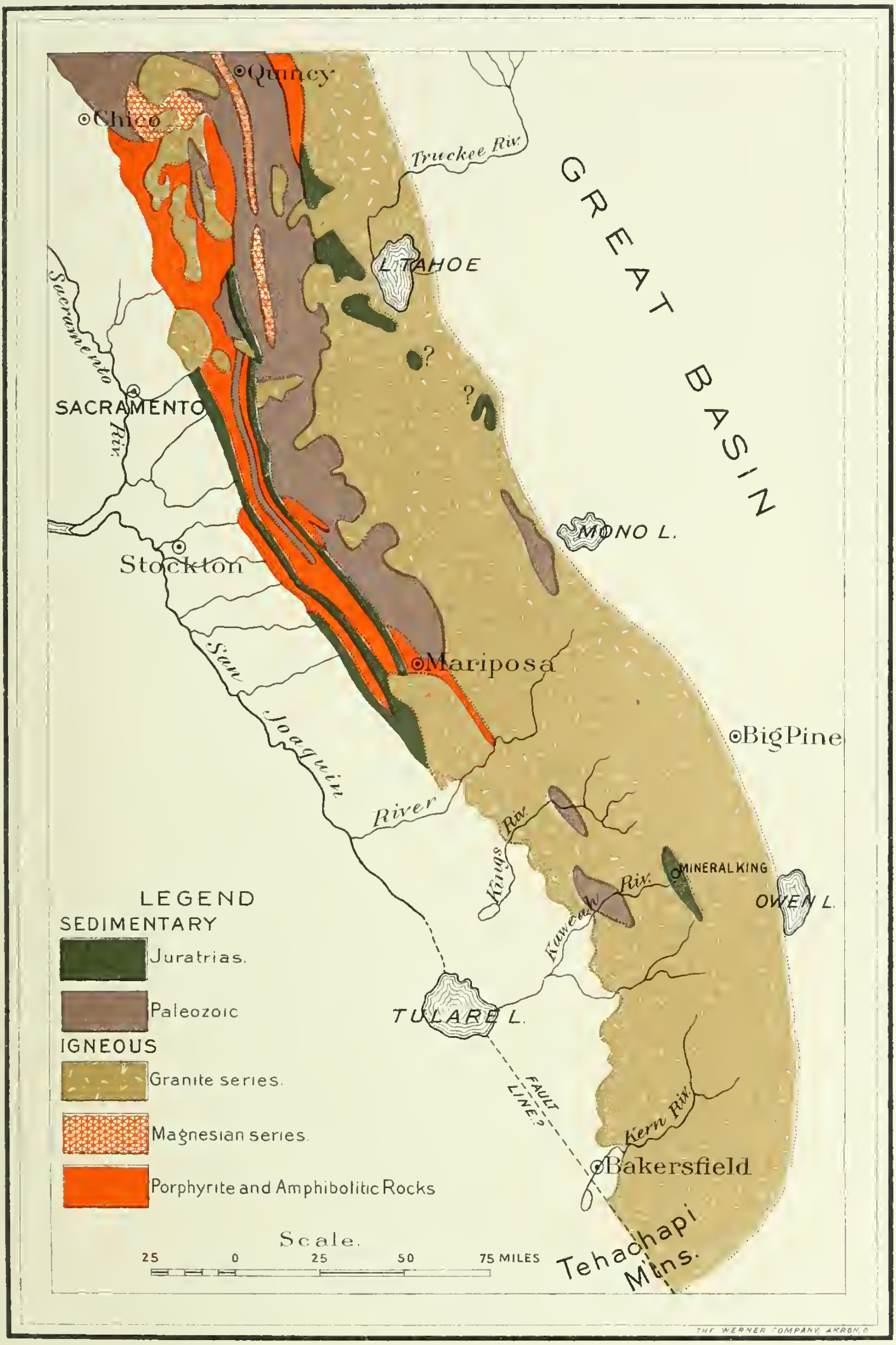
In a recent paper Walcott[3] expresses similar views as to the structure of the ranges of southern Nevada, as follows:

As seen from the western slope of the White Mountain range, the next range to the eastward, Silver Peak, is apparently a monocline facing westward; but from the known structure of the Great Basin ranges, such as those of the Eureka district,

[1] Fortieth Parallel Survey, Systematic Geology, Vol. I, p. 744.

[2] Some of the Miocene beds of King are said by Russell to be of later age

[3] Am. Jour. Sci., Vol. XLIX 1895, p. 174.



GEOLOGIC MAP OF THE OLDER FORMATIONS OF THE SIERRA NEVADA.

Nevada, the Oquirr Range, Utah, and others illustrated by the geologists of the Wheeler survey, it appears that in the broad Paleozoic area between the Sierra Nevada on the west and the early Paleozoic shore-line on the east (Colorado) a period of folding and thrust faulting was followed by a period of vertical faulting, which displaced the strata that had been folded and faulted in the preceding epoch. The extent and character of this disturbance can be determined only by a careful study of each of the mountain ranges for a distance of over 500 miles east and west and probably 1,000 miles north and south; and the great geologic problems will not be fully solved until the areal geology of the region between the one hundred and ninth and one hundred and nineteenth meridians shall have been mapped.

In 1889 Prof. Joseph Le Conte[1] published a paper on the "Origin of normal faults," in which he graphically pictures the formation of the Basin ranges. One of his figures is reproduced here (fig. 18). If taken in a general way, Professor Le Conte's illustration and explanation seem to the writer to express a general truth. He writes:

The whole region from the Wasatch to the Sierra inclusive was lifted by intumescent lava into a great arch, the abutments of which were the Sierra on the one side and the Wasatch on the other. * * * The arch broke down and the broken parts readjusted themselves by gravity into the ridges and valleys of the Basin region, leaving the abutments overlooking the basin and toward one another. It must

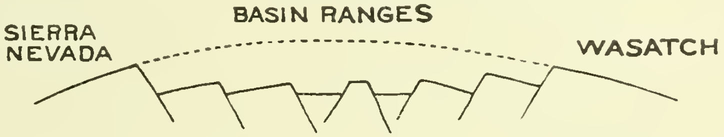


FIG. 18.—Diagram showing hypothetical mode of formation of the ranges of the Great Basin and of the Sierra Nevada and the Wasatch.

not be supposed, however, that this took place at once, but gradually, the lifting, the breaking down, and the readjustment going on together *pari passu*, each readjustment probably giving rise to an earthquake.[2]

Professor Le Conte recognized, however, that the Sierra and the Wasatch had existed as ranges previous to Tertiary time, but supposes their height to have been increased at the time of the normal faulting. His remarks on the Sierra Nevada and Basin ranges contain practically nothing new, being based on the earlier publications of Whitney, King, Gilbert, Russell, and others.

ARCHEAN GNEISS IN THE SIERRA NEVADA.

The geologists of the Fortieth Parallel Survey were of the opinion that western Nevada is part of an Archean area which during Paleozoic time formed a land mass. The following quotations from Clarence King[3] are a condensed statement of the evidence:

Considered as a whole, the Paleozoic series thickens to its western limit on longitude 17° [117°] 30′. West of that meridian there is a sudden remarkable change in the whole geology. No more Paleozoic rocks are observed in Nevada, and in California

[1] Am. Jour. Sci., Vol. XXXVIII, p. 262.

[2] For further notes in this connection, see Le Conte's papers and Mohawk Lake Beds, Bull. Philos Soc., Washington, 1891, which contains references to the literature.

[3] Systematic Geology, 1878. p. 247.

only inconsiderable deposits of Carboniferous. Over the whole basin of Nevada the oldest post-Archean rock is the Trias, which lies directly on the old Archean mountain slopes, without interposition of Paleozoic beds. It is immediately evident that the Paleozoic never extended over that region; in other words, that western Nevada formed during Paleozoic time a continental mass which bounded the ocean in that direction, and where continued degradation furnished the greater part of the sediment that was spread out on the sea bottom.

Fourteen years later Arnold Hague wrote:[1]

In all probability the Paleozoic ocean in Nevada presented an indented shore line with a general northeast and southwest trend. * * * This ancient shore line has never been traced, consequently its outlines are most indefinitely determined. It is obscured by enormous quantities of erupted material in places literally mountain high, burying for long distances all traces of preexisting rocks. * * *

Ranges situated eastward of the supposed shore-line expose above flows of rhyolite long ridges of quartzite which have been referred to the Paleozoic age. They are at all events quite unlike the rocks of the region to the west. * * To the south the shore-line probably ran out toward the California boundary. * * * Along the shore the conglomerate forms heavy masses of material, indicating littoral deposits, but to the east the same formations gradually pass into finer-grained sandstones, the beds in general becoming more uniform in character.

Rocks of Cambrian age have been found at Eureka, Pioche, at the south end of the Timpahute Range, at Silver Peak, and lately by Walcott[2] in the White Mountains of Inyo County.[3] As Walcott's discoveries are of great importance to the student of the geology of the Sierra Nevada, the following extracts from his paper are presented:

The only Lower Cambrian rocks of California known to me occur in the White Mountain range of Inyo County, east of Owens Valley, with a single exception of one small mass west of Big Pine, which is in the foothills of Sierra Nevada. * * * The entire section, briefly summarized from summit downward, is as follows:

	Feet.
4. Upper arenaceous beds	200
3. Alternating limestones and shales	1,000
2. Siliceous slates and quartzites	2,000
1. Siliceous limestones	1,700
Total	4,900

* * * No fossils were found in the lower limestones (1). Numerous annelid trails occur in the lower siliceous series (2), and in the slaty portion near the summit heads of Olenellus were found. In places the lower portion of the upper limestone series is almost a solid bed of different forms of *Archæocyathinæ*. *Ethmophyllum whitneyi* Meek is very abundant, and the genera *Protopharetra*, *Coscinocyathus*, and probably *Archæocyathus* occur. Ethmophyllum ranges throughout the limestone series into the base of the shales in Tollgate Canyon, where it is associated with Cystidean plates and fragments of Olenellus. On the north side of Silver Canyon the Archæocyathinæ are so abundant in the limestone that it may practically be called a Lower Cambrian coral reef. This reef was traced for nearly 30 miles, and the same types are also known to occur in the Silver Peak Range, about 25 miles to the eastward.

[1] Mon. U. S. Geological Survey, Vol. XX, 1892, p. 176.

[2] Am. Jour. Sci., Vol. XLIX, 1895, p. 141.

[3] The south end of this range is called the Inyo Mountains, and as this is a very distinctive name it would seem better to call the entire range the Inyo Mountains and to retain the name White Mountains only for the particular peak which is now so called.

So far as known to me, this is the oldest of the Cambrian faunas in the western portion of the United States. Just what its relation to the Olenellus fauna of central Nevada and British Columbia is, I am at present unable to state, except that I believe it to be older than the Olenellus fauna of central Nevada.

In another paper[1] Walcott describes the Appalachian type of folding in these Cambrian rocks and gives several sections. He has made out that a syncline forms the flanks of the Inyo or White Mountains east of Bishop Creek and Big Pine. This had, however, as he states, been previously indicated by Prof. G. K. Gilbert[2] for the region east of Big Pine. The oldest rock found, the lower limestone, is exposed in the lower foothills of the range just east of Owens Valley, and, in consequence of the northern pitch of the syncline, passes beneath the Pleistocene beds on the margin of the valley before reaching Silver Canyon, which is nearly east of the town of Bishop Creek. No fossils were found in the lower limestone, but Mr. Walcott was not able, from lack of time, to search carefully for them. Some of his general conclusions are as follows:

Viewing the White Mountain Range from the western slopes of the Sierra Nevada, north of Big Pine, it is evident that several transverse or oblique faults break the syncline that rests on the western slope of the range. The strata are displaced on the south side of Black Canyon, and also about 5 miles to the north.

It is thus evident that the most promising region to search for Algonkian or Archean rocks is in the neighborhood of Owens Valley, for if gneisses or other Azoic rocks are there found it may be practicable to determine their position below the Cambrian, and thus obtain more positive proof of their age than has thus far been found, for nowhere in the Great Basin or in the Sierra Nevada have the Cambrian rocks been seen to rest directly upon older schists or gneisses.

Professor Gilbert, however, states that near Deep Spring, in the Inyo Mountains, there are gneissic rocks associated with the granite. Attention might here also be called to a granitoid rock collected by Walcott near Deep Spring Valley. This proved to be a hornblende-syenite and is briefly described in Chapter VI of this paper and in the American Geologist for June, 1896.

Prof. J. D. Whitney has noted some gneissic areas in the southern Sierra Nevada which may prove to be part of the Archean Complex, and his description is herewith appended:[3]

From Tahichipi (Tehachapi) Valley down the creek of the same name, to its junction with Cottonwood Creek, granite and gneiss are the predominating rocks, but some mica-slate was observed, especially near the mouth of the canyon, where it forms rounded hills bordered by the Tertiary of the Tulare plain. The strike of the gneiss, which makes up the larger portion of the formation, is nearly north and south, and it dips at a high angle to the east, being much contorted and often cut by veins of milk-white quartz, which run at right angles to the strike of the inclosing rock. Some of these quartz veins are of very large size.

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[1] Am. Jour. Sci., Vol. XLIX, 1895, p. 169.
[2] U. S. Geol. Surveys West of the 100th Meridian, Vol. III, Geology, 1875, pp. 34 and 169.
[3] Geology of California, Vol. I, p. 218.

From Cottonwood Creek, our party crossed over to Walker's Basin, "the park" of the Pacific Railroad Reports. The trail led up Cottonwood Creek and Pass Creek, a branch of the first named, and then over a sharp and steep ridge, the rocks being exclusively gneiss and mica-slate, the former predominating. There is a considerable soil on the ridge and a pretty good growth of timber. In the canyon of Pass Creek are many bowlders of limestone, indicating a considerable mass of this rock somewhere to the east.

Walker's Basin, or Valley, is a triangular area surrounded on all sides, except a portion of the southeast, by high mountains, the highest peaks east and west being fully 7,000 feet in altitude. Canyon Mountain, on the west, has very large exposures of bare rock, consisting of granite and gneiss, beautifully and distinctly bedded or stratified, with a strike of N. 75° E., and a nearly vertical dip. The high mountain lying northeast of the valley is of the same character, with rather more granite, having a north-northwest strike and northeast dip.

A low divide, perhaps 1,000 feet above the general level of Walkers Basin, separates it from the valley of Kern River. In the ridge are mica-slate and gneiss, trending about N. 60° W., and dipping at a high angle, sometimes north and sometimes to the south. These rocks continue along the trail nearly to Kern River, and some granite is associated with them.

Prof. W. P. Blake[1] refers to some gneissic rocks in the Tehachapi Mountains at Cañada de las Uvas, and the mica and hornblende slates noted as occurring in the Tejon Pass may be also of the same series.

About 1888 Dr. G. F. Becker made a small but interesting collection of gneisses and granites in the Cañada de las Uvas, and kindly placed these at the writer's disposal. Only a cursory examination has been made of these rocks, but it is certain that they contain true gneisses, which are cut by dikes of quartz-mica-diorite and granulite. Quartz, plagioclase, hornblende, biotite, green monoclinic pyroxene, titanite, and garnet are the chief components of the gneisses so far as examined. Dr. Becker states that they are well banded and sometimes plicated.

It is evident that if western Nevada formed an Archean land mass in Paleozoic time, the western border of this land mass formed the eastern shore of the sea in which the Paleozoic sediments of the Sierra Nevada were laid down. On account of the intrusion, about the close of the Juratrias, of large masses of granitic rocks in the Sierra Nevada and the folding and crushing that occurred at that time, this hypothetical western shore line was greatly obscured, and has not thus far been indicated with certainty at a single point.

In 1891 the writer found in the canyon of the north fork of the Mokelumne River, to the east of Devils Nose in the Big Trees area, a series of foliated crystalline rocks, and later published[2] a short statement concerning them.

In 1895 the writer again visited the region and made a more careful study of these gneisses and associated granites. His collection was examined by Prof. C. R. Van Hise, who was impressed with their resemblance to the rocks of the fundamental complex (the Archean) of the Lake Superior region. A comparison of the granite which forms a part of the gneiss series with the so-called Archean granites of the West Humboldt Mountains in the collection of the Fortieth Parallel Survey shows that they are strikingly similar.

[1] Pacific Railroad Reports, Vol. V 1857, p. 209.
[2] Am. Geologist, Vol. XIII, 1894, p. 229.

The gneisses of the Big Trees area are chiefly pyroxene-biotite-plagioclase-gneiss, hornblende-biotite-plagioclase-gneiss, and quartz-hornblende-biotite-plagioclase gneiss. A more careful description of them is given in the chapter on the Big Trees area. The gneisses of the Mokelumne Canyon are not, however, represented by a precisely similar series in the West Humboldt Mountains, so far as could be determined by a cursory examination of the specimens in the Fortieth Parallel Survey collection, most of the Archean rocks of which are various kinds of knotted schists, and if the biotite-granite called Archean is intrusive in these schists its age may be Algonkian or later, and not Archean, and this would likewise be true of the similar granite found folded in with the Mokelumne gneisses.

THE MODE OF FORMATION OF THE ANDESITE BRECCIA AND TUFF.

The most abundant lava of the Tertiary volcanic period was andesite, which occurs chiefly in a fragmental form.

Fragmental volcanic rocks are usually supposed to have been formed by explosive action, the material being thrown out as fragments and ashes, which, falling on the surrounding land or in bodies of water, would in the former case assume a roughly and in the latter case a definitely stratified shape. But this does not appear to form an adequate picture of the Pliocene eruptions of the Sierra. The fragmental lava appears to have been mixed with water, perhaps derived from melting snow at or very near the sources of the eruption. But however these mud flows were formed, on their course down the slopes of the range they caught up much foreign material.

Silicified trunks of both deciduous and coniferous trees, bowlders of granite, some of them tons in weight, and pebbles and fragments of nearly all the older rocks of which the Sierra Nevada is composed, are found embedded in the andesitic material.

Along the east side of the Great Valley of California these andesite tuffs grade into well-stratified material containing abundant rolled sand grains, and such beds may be regarded as water deposits. A most remarkable fact has been noted by the writer in regard to these tuff areas, namely, that wherever the original top layer of the beds has been preserved this is, so far as observed, a distinct breccia, composed chiefly of angular fragments and blocks cemented by ashes, while below are layers of fine tuff and volcanic conglomerate, with some layers, especially in the foothills, in which pebbles of pre-Cretaceous rocks are abundant.

As forming a possible representation of the way these andesitic fragmental lavas attained their present position, two quotations are here given from descriptions of eruptions of volcanoes in Japan and in Java within the historic period. The eruption of the Japanese volcano (Bandai-san) should be rather called an explosion, a very large portion of the upper part of the mountain being blown off, and there being no new volcanic material formed. The account of the eruption of the Javanese volcano was written after an extended examination of it in 1843 by Mr. Junghuhn, and is based on this examination and on a more or less unreliable account written at the time of the eruption by J. M. Mohr, the preacher at Batavia, which is about 100 miles distant. This account appears to have been based on the reports of natives, and was not considered accurate by Mr. Junghuhn. Only so much of this account is given as seems necessary to show the resemblance between the Javanese and the Japanese volcanoes. In the case of the former volcano there appears to have been fire emitted.

In comparing these eruptions with those that took place in Tertiary times in the Sierra Nevada, this difference should be borne in mind, that while the material in the Javanese and Japanese volcanoes traveled but a few miles and down a comparatively steep grade, there is excellent evidence that most of the sources of eruption in the Sierra Nevada were along the crest of the ridge, and that the fragmental material was transported from these sources to the border of the Sacramento Valley, a distance of about 50 miles, on a comparatively gentle slope. Volcanoes may have existed, however, at some points in the foothills; Jackson Butte, for example, may be an old volcanic core.

THE ERUPTION OF BANDAI-SAN, IN JAPAN.

By S. SEKIYA and Y. KIKUCHI.[1]

The most striking feature in the whole of this eruption was the deluge of rock and earth. Notwithstanding the violence of the phenomena, and the completeness with which the mountain was destroyed, the nature of the eruption was comparatively simple. The destructive agency was merely the sudden expansion of imprisoned steam, unaccompanied by lava flows or pumice ejection. When the explosion took place, a considerable amount of rocks and earth was projected into the air, and a part diffused in the form of dust, but by far the greater part of the bulk of Kobandai was just split into mighty fragments, which were thrown down much after the manner of a landslip. Descending the mountain sides with ever-accelerating velocity, the components of these avalanches were dashed against obstacles in their way and against each other, and were thus rapidly reduced to confused masses of earth and rocks. The loose and friable débris thus produced ultimately lost its adhesive power, and might be compared, with a little exaggeration, to sand. If we suppose a mass of some 1.21 cubic kilometers, or 1,587,000,000 cubic yards (which was the actual volume of the mountain destroyed), of sand to be suddenly precipitated from a lofty summit, it would flow down the sides in a torrent not very unlike that of water. That the earth and rock débris did flow down in this way we were convinced by examining the actual state of things on the spot, and more particularly by witnessing afterwards with our own eyes a very similar phenomenon, though on a vastly smaller scale. * * *

The descending matter must have moved with great velocity. By some survivors it was described as having reached their vicinity almost instantly after the eruption. From several calculations, made by comparing the time of the explosion with the time at which the streams of débris arrived at different points, we roughly estimated the average speed to have been 77 kilometers, or 48 miles, per hour. On its course the mud stream must have swelled into great waves, as in a surging current. This

[1] Trans. Seismological Soc. of Japan, Vol. XIII, pp. 139-222. The eruption occurred on July 15, 1888. The authors arrived at the volcano on July 19 and remained till October 8. The writer is indebted to Mr. G. K. Gilbert for calling his attention to these papers.

is attested by eyewitnesses. The wave-like traces left on the sides of the hill show how the torrent surged upward when it met any obstacle either obliquely or at right angles. In one case near Kawakami, the earth reached a height of at least 40 meters above the general level on a hill facing the direction of flow, and at other places a spur of the hill which the current struck obliquely caused an uprush of from 30 to 60 meters. The general appearance of the present surface is one of extraordinary havoc and confusion, irregular lumps of earth being mixed up with torn-off trunks and branches of trees, fragments of timber, and stray bowlders of huge size. In some places the matter has been largely admixed with water, and is treacherous to walk on. * * *

In describing the phenomena of the earth and rock débris, the word "mud" has been frequently used by several observers, who speak of "mud stream," "mud field," etc. We have used the term above, but it must be explained, to avoid misconception, that we have done so for convenience only. Some commentators, indeed, have erroneously classed the phenomena with those of the "mud volcanoes," of which we read in geological text-books that, while some have been known to throw up mud to a great height, in others liquid earth only oozes out quietly, and gradually forms an earth ring around the crater. Such outbursts, however, are no more than moderate manifestations of subterranean energy, and are almost insignificant in comparison with the tremendous forces that destroyed Kobandai-san. Moreover, as far as our prolonged examinations went, there was no evidence of any discharge of mud from beneath. It is true that in the Nagase Valley and other places there are now immense quantities of mud, but these became mud only after the eruption. During its descent, for example, a part of the débris, mingling with the waters of ponds and lakes in its course, doubtless acquired a muddy character and was thus assisted in its flow; and, again, that which reached the stream of the Nagase-gawa became admixed with sufficient water to thin it to the consistency of a paste. But by far the greater volume was in a comparatively dry state, being moistened only by condensing steam, and must have derived its fluid or semifluid properties from a rapid process of pulverization after the manner already described. * * *

On reaching the outposts of the mud field, no one could help being struck by the singular way in which the advancing stream of rock and earth seemed to have suddenly stopped, showing a vertical or nearly vertical face, a few meters high. It is apparent that the débris of rock and earth, in their swift descent, behaved like a fluid, but on nearing to the plain below they gradually lost speed and were ultimately brought to rest; the materials that followed, on account of their great friction and adhesion, could not pass the limit set by their predecessors, and were piled layer on layer, thus forming a steep edge.

It is manifest that the immediate cause of the eruption was the sudden expansion of steam pent up within the mountain. Of lava or pumice there is no trace. The gray-colored ashes, which form a chief product of the explosion, are evidently the powder of preexisting rocks decomposed by the action of fumaroles, and have not been derived from fused magma.

THE ERUPTION OF GUNUNG PEPANDAJAN, IN JAVA.

By FRANZ JUNGHUHN.[1]

Exactly such streams of lava débris as present themselves here at the Gunung Pepandajan as the products of the eruption of 1772 were ejected by the Gunung Gelunggung in 1822. Only this difference seems to exist between the two eruptions, that the volcanic ashes in the last-mentioned eruption were mixed with the water of a reservoir, probably existing in the crater, into mud or slime, and that the débris mass was rolled down together with this mass of mud or buried in it, while in the eruption of the Gunung Pepandajan, whose crater did not inclose a water reservoir, the débris probably consisted of dry material.

[1] Java, seine Gestalt, Pflanzendecke und innere Bauart, Leipzig, 1854, Vol. II, p. 104. The translation is by Robert Stein.

CHAPTER II.

THE CHICO AREA.

SUPERJACENT SERIES (CRETACEOUS AND LATER).

THE TUSCAN TUFF.

The first elevations that the traveler meets with in Butte County, in going eastward from the alluvial plains of the Sacramento Valley at Chico, are level-topped ridges which plainly show at numerous points a bedded character. They can nowhere be better seen than in the canyons of Butte and Chico creeks. A more careful examination of these stratified beds shows them to be made up largely of volcanic material. In the Chico sheet area they are, in fact, chiefly basaltic tuffs, and have been designated the Tuscan formation by Diller in his description of the geology of the Lassen Peak region.[1] These tuffs resemble in a general way the andesitic tuffs and breccias of the region to the south of the North Fork of the Feather River, but numerous examinations made by the writer in the area of the Chico sheet show that the material is chiefly basaltic, and without doubt came originally from the vents of the Lassen Peak volcanic area. The Tuscan formation is probably in large part younger than the andesitic tuff series, for the coarse doleritic basalts which form the main material from which the tuffs are derived are unquestionably later than the andesitic lavas of the region.[2]

The Tuscan tuff covers a very considerable part of the central and northern portions of the area of the Chico sheet. None of it is known in the Bidwell Bar sheet area. It overlies the sandstones of the Chico formation in the neighborhood of Pentz, and in the canyon of Butte Creek near Cente.ville, and along Chico Creek about 7 or 8 miles northeast of Chico. Here is also a flow of the older basalt, like that of the Oroville Table Mountain, resting on the Chico sandstone and overlain by the Tuscan tuff, which at this point is 400 feet or more in thickness, as estimated from the contours of the map.

General Bidwell, of Chico, called the attention of the writer to certain tube-like holes in the tuff along Chico Canyon. These holes have a diameter varying from one half inch to 2½ inches. They may have been

[1] Lassen Peak folio, Geologic Atlas of the United States, folio No. 15. See also Fourteenth Ann. Rept. U. S. Geol. Survey, pp. 412 and 428.

[2] Fourteenth Ann. Rept. U. S. Geol. Survey, pp. 492, 493.

occupied by branches of trees now rotted out. The stratified nature of the tuff is finely seen in the canyon of Butte Creek by the road to Magalia, where it forms bluffs, in places weathering into shapes resembling castles.

The Tuscan tuff contains, however, much material that is not basaltic. Bowlders, fragments, pebbles, and fine detritus of andesitic lavas and of the older igneous and sedimentary rocks occur in it, as would be expected from its mode of formation. In the neighborhood of Pentz much of the lower portion of the tuff appears to be of andesitic origin.

This was noted in 1885 in a little butte about a mile west of the hotel at Pentz, where are also found, included in the tuff, pebbles of the older lava (basalt) of the Oroville Table Mountain. The same relation is shown at Welch's hydraulic gravel mine, 1½ miles north of Pentz. This was examined with some care by Diller, who has kindly placed his notes at the writer's disposal. It was also examined and specimens collected in 1895 by the writer.

The hydraulic mine is plainly to be seen from Pentz. It is at the south point of a spur of the table of tuff that continues thence north to Magalia and beyond. Resting on slates of Paleozoic age is a layer of coarse angular gravel of local origin, composed chiefly of the older igneous and metamorphic rocks. This is from 10 to 15 feet thick and presumably contained most of the gold. Overlying this is about 70 feet of fine sediment of a black color and further discolored by iron sulphate. All of this material appears to have been washed by hydraulic method.

The next layer is made up of rusty sediments about 10 feet in thickness, and contains waterworn pebbles of quartz and siliceous metamorphic rocks, and is especially remarkable as containing abundant fragments of the black fine-grained basalt (No. 900 S. N.) of the Oroville Table Mountain, which is only 2 miles distant. These fragments, many of which are from 3 to 6 inches in major diameter, are not noticeably waterworn. This layer appears to give evidence that the Table Mountain had been uplifted and was undergoing erosion at the time the layer was being formed. Overlying the layer with the basaltic fragments is about 50 feet of soft, light-colored, and very fine-grained sediment or tuff in which are some coarser but still fine grained brownish layers (No. 901 S. N.), a microscopic examination of which shows the brown friable material to be a true tuff, made up of microlitic fragments and of broken crystals of plagioclase (in part labradorite), angite, hypersthene, and brown hornblende, all of which are abundantly represented. As the basalts of the region carry little if any brown hornblende, it is very probable that much of this tuff is of andesitic origin. No olivine was noticed in the thin sections examined. Overlying this fine sediment is a harder 4-foot layer of a dark color, which was first observed from our camp at Pentz. This (No. 902 S. N.) is a basaltic tuff. It is coarser than 901, and is made up of microlitic fragments of black, red, and other colors, with some fragments of feldspar, augite, hypersthene, and brown hornblende. Several of the microlitic fragments contain olivine. From this layer to the top of the table, a vertical distance of about 150 feet, all is tuff with more or less gravel and angular fragments of lava, much of which is basaltic. One layer about 10 feet thick in this mass of tuff is composed of well rounded lava pebbles, and the top is a heavy bed of dark breccia. The succession made out above may be tabulated as follows:

Section at Welch's hydraulic gravel mine, 1.5 miles north of Pentz.

	Feet.
1. Base. Paleozoic slates dipping at a high angle.	
2. Angular gravel	10
3. Sand and gravel	70
4. Sand, quartz pebbles, fragments of the older basalt	10
5. Very fine tuff of andesitic detritus	50
6. Tuff, conglomerate, and breccia; largely basaltic	150
Total thickness about	290

All of the above distances were merely estimated, and not measured. There are also intercalated in the tuffs flows of massive basalt at various points. One of these flows is well exposed along a ditch in the west side of Shake Ravine, 5 miles[1] northeast of Magalia. This flow (No. 922 S. N.), about 20 feet in thickness so far as exposed, rests on the Tuscan tuff. The exposure is interesting as showing the beginning of the formation of spheroidal blocks by exfoliation due to decomposition. The corners of the blocks are being plainly rounded, and concentric lines of decomposition surround each of the originally approximately rectangular blocks. At one time these blocks, which are superimposed in a very regular manner, almost as if laid by the hand of man, were undoubtedly parts of one massive flow, the intersecting cracks along which decomposition has proceeded being produced at a later date, perhaps as a result of cooling.

Another massive flow (No. 906 S. N.) of scoriaceous lava, 12 to 15 feet in thickness, is exposed along a ditch on the west side of the West Branch of the North Fork of the Feather River, about 9 miles northeast from Magalia, to the north of where the Kimshew road crosses the West Branch. This is an olivine-rich basalt and is near the base of the Tuscan tuff formation, which at this point forms the ridge to the west, having a thickness of 400 feet or more. At the south end of this lava flow may be seen some distinctly sedimentary material, but, as the Tuscan tuff forms the banks of the river above the bridge of the Kimshew road, it probably underlies both the distinctly sedimentary material and the lava flow. Between the bridge and the mouth of Fish Creek, 1½ miles to the north, where not covered by Pleistocene gravel, the tuff forms both banks of the stream. The tuff along here, at most exposures seen, is rather fine grained, but there are also extensive layers of gravel

[1]All distances in this paper are in an air line.

in which are embedded blocks of lava 3 feet in diameter. The large bowlders occur more abundantly higher up in the ridge. The stratification of the tuff along the West Branch is sensibly horizontal. In addition to the volcanic gravel it contains well-worn pebbles of quartz-diorite, which here underlies the tuff formation.

ANDESITIC TUFF SERIES.

This series, so extensively developed in the central Sierra Nevada, may be seen in the southeast corner of the Chico sheet area, to the east of Oroville. As before estimated, it is thought to be older than at least the greater part of the Tuscan tuff formation. As already noted, the lower portion of that formation near Pentz is made up of andesitic detritus.

THE OLDER BASALT.

It has been shown in previous papers that this black fine grained basalt is older than the hornblende-pyroxene andesite. However, it is quite certain that some andesitic eruptions took place before the older basalt flows, since pebbles occur under the Oroville Table Mountain basalt. To the west of Table Mountain are a number of little buttes which are regarded as detached outliers of the main flow, and presumed to have been connected with it. The flow is supposed to have originated higher up in the mountains. The highest point of Table Mountain is near Cherokee, where the altitude is more than 1,600 feet, thence sloping gently to the southwest, some of the outliers to the west of South Table Mountain, which do not appear to have been displaced, having an altitude of less than 500 feet above sea level. In one of these buttes a shaft is said to have been sunk 200 feet in sand and gravel without reaching bed rock. A number of small masses near these outlying buttes, with an altitude of 300 feet or less, have probably been displaced by the erosion of the softer Ione formation underneath. The slope of the table suggests that its source should be looked for to the northeast of Cherokee. Nevertheless there is no similar basalt in that direction nearer than the Walker Plains, a distance of 17 miles. The small area of basalt-like lava (No. 150 Butte) on the southwestern spur of Big Bend Mountain, differs in habitus from the older basalt, and may be a dike. It may be supposed that the Ione beds underlying the flow were elevated above water before the flow took place, for so far as noted the lower layer next to these beds is not scoriaceous, as would presumably be the case with lava flowing over a water-covered surface. At two points dike-like masses of the basalt appeared to cut the Ione beds. One of these points is by the road just southwest of the west end of South Table Mountain (Pl. XIX), the same point where andesite pebbles were noted. Here the basalt (No. 188 Butte) contains porphyritic feldspars, but is otherwise quite like that of the Table Mountain. The other point is about a mile west of Wick's ranch. This dike (?) extends westerly across the adjoining stream bed. The rock seemed in place at both of these points, and a more careful examination may show that these are dikes, though it is conceivable that they may represent cracks in the soft Ione beds, filled in from above, or simply displaced masses. An analysis of the basalt of the Oroville Table Mountain (No. 18 S. N.) will be found in the table of analyses of basalts.

The basalt flow (Butte Co. No. 1) exposed in Chico Creek rests on Cretaceous sandstones, to be described later. The narrow gorge formed by the creek cut ing through the black basalt, which is here about 200 feet in thickness, is known locally as Iron Canyon. For some hundreds of feet both north and south of this gorge the overlying Tuscan tuff has been eroded, leaving the upper surface of the flow exposed.

AURIFEROUS NEOCENE SHORE GRAVEL.

Of late years certain gravels underlying the Tuscan tuff have been largely mined for gold. Their exact age is not certain, and different deposits may differ considerably in age. It is probable, however, that they all belong to the Neocene (Miocene and Pliocene) period. They are found chiefly on the ridge west of the West Branch of the North Fork of the Feather River. These gravels have been and are being mined at a number of points, and have sometimes proved highly auriferous. One of these mines visited by the writer in 1895 is on the Little West Branch of the North Fork of the Feather, 2 miles northeast of Magalia, the opening of the incline being about 12 feet above the bed of the stream. On the east side of the stream the bed rock, here serpentine, rises 400 feet at a steep angle, forming a spur between the Little West Branch and the main West Branch. The ridge to the west of the Little West Branch is here made up, from base to summit, of the Tuscan tuff. The mine is known as the Alki or Parry mine, and was also visited by Mr. Diller, and by Mr. J. A. Miner[1] of the State mining bureau. The information gathered from the man in charge at the time of my visit indicates that the incline followed down the bed rock in a westerly direction, sometimes cutting through it, for a distance of about 900 feet, at an average angle of about 22°, so that the incline at its lower end was 350 feet vertically below the mouth. The gravel on the bed rock for the first 100 feet was auriferous; then came a stretch of some hundreds of feet where the lava (Tuscan tuff) and the bed rock came together, after which the incline has a smaller dip, and gravel on the bed rock was again found. The information obtained by Diller in 1893 differs only in details from that given above, and he came to the conclusion that the gravels were of shore origin. He states that the lower gravel is waterworn.

The Lucretia or Perschbecker mine on Little Butte Creek about 2

[1] Tenth Ann. Rept. State Mineralogist California, 1890, p. 141. See also Eleventh and Twelfth Repts. State Mineralogist.

OROVILLE TABLE MOUNTAIN.

miles nearly due north from Magalia, which has produced[1] more than $1,000,000 in gold, appears to be also in shore gravels. This mine was very extensively advertised in the San Francisco papers in 1894.

The gravels at the Magalia Consolidated or Mineral Slide mine[2] rest partly on slates and partly on Cretaceous sandstones. The tuff overlying the gravel has a thickness of about 575 feet. The sandstone 150 feet below the gravel contains Cretaceous (Chico group) fossils. Mr. Moody, the superintendent, thought the gravel (4 to 10 feet thick) to be a bed or sheet and not a stream deposit. Mr. Moody is also authority for the statement that a mastodon jawbone was found at Mineral Slide some years ago, and was represented in San Francisco as coming from Mexico. The soft Cretaceous sandstone is here called the bed rock. The buildings are on slate, against which the Chico beds abut. The slate does not extend farther up the creek. On the west side of Little Butte Creek, opposite Mineral Slide, is the Eureka mine, working on the same gravel bed.

Two miles and a half north of Pentz, on Dry Creek, the Corey Bros. have run a tunnel west and found some gold. On the east side at the same place a tunnel has been run east for 600 (?) feet on slate bed rock. The gravel is coarse and subangular and about 25 feet thick. Over it is clay, sand, etc. In 1885 the writer visited the Red Gravel hydraulic mine. This is on the south side of Butte Creek Canyon opposite Centerville. The gravel attains a thickness of 75 feet and rests directly on Cretaceous sandstone containing fossils of the Chico group. This gravel deposit was supposed to extend under the tuff, which begins a few rods to the south. Among the pebbles were some of pre-Tertiary quartz-diorite-porphyry and diorite-porphyry (Butte Co. Nos. 9 and 10) and of a Tertiary-looking olivine basalt (No. 11). On the north side of the canyon, near Helltown, several hundred feet above the creek and likewise resting directly on the Cretaceous sandstone, is a deposit of gravel which was well exposed in a tunnel run in for mining the gravel. Capping the deposit is the Tuscan tuff series, the lower layer of which is a volcanic conglomerate containing pebbles of hypersthene-basalt (No. 13). Among the pebbles of this deposit were some of the older basalt (No. 15) like that of Oroville Table Mountain; and as this basalt is obviously younger than the Ione formation which it covers, it follows that this gravel bed is also of younger age than the Ione formation.

There are many other points where these shore gravels under the Tuscan tuff have been mined. So far as known to the writer, at no point has a well-defined channel with definite banks been shown to exist. It is more than probable, however, that some of these gravel deposits occupy swales in the uneven surface of the underlying bedrock, and may therefore, for short distances, simulate a river channel.

[1] Eighth Ann. Rept. State Mineralogist California, p. 119.

[2] Twelfth Ann. Rept. State Mineralogist, p. 96. The notes about this mine, as well as those about the Eureka and the Corey Bros., are chiefly by Mr. Diller.

A clear idea of the nature of these gravels is of great importance to the miner, and if Diller and the writer are correct in regarding them as shore gravels, it follows that the miner must not expect to find continuous beds, but that they will occur in an intermittent manner and at various elevations, and can not therefore be continuously followed for long distances, as has been done with the old river channels, especially in Yuba, Nevada, and Placer counties.

The extreme unevenness of the underlying surface of the bed rock along the old shore line is remarkable. It seems explicable only on the supposition of a considerable depression of the land before the period (late Pliocene?) when the Tuscan tuff was deposited. The tuff, as previously noted, forms the bed of the West Branch above the Kimshew bridge, the ridge to the west being composed from base to summit of the tuff, but the ridge on the east side below the bridge is composed entirely of the older rocks and rises 1,500 feet in the horizontal space of 1 mile and 2,500 feet in 2 miles above the level of the river, or, in other words, above the bed-rock surface on which the tuff was deposited. The steepness of the former shore line may be seen again near the mouth of the Little West Branch, at the Alki gravel mine, as before noted. The tuff here is at the level of the stream bed, and the ridge to the west is entirely made up of tuff, but the ridge to the east is entirely of serpentine and other rocks of the pre-Cretaceous series, and this shore bottom rises 300 feet vertically in about one-fourth of a mile.

THE IONE FORMATION.

This is most extensively developed, so far as known to the writer, chiefly about the Oroville Table Mountain, where it attains a thickness of about 500 feet. As has already been noted,[1] these beds are in places auriferous, and it is by no means improbable that the gravels at some of the mines described above belong to this formation. Indeed, this is the view held by Diller,[2] though the writer understands that except at the Oroville Table Mountain no fossil leaves or other evidence of age has been obtained in the Chico sheet area. That portion of the area, however, to the north and west of Chico Creek has not been explored by the writer.

The Miocene hydraulic mine is at the east edge of South Table Mountain. The deposit is largely sand and white clay, containing fossil leaves, with gravelly layers made up chiefly of white quartz pebbles. Professor Knowlton identified one of these leaves as *Juglans californica* Lx. The bed rock is a greenstone breccia, representing an original augitic surface lava, probably an andesite. The sedimentary beds are perhaps 300 feet in thickness, capped with a basalt sheet about 100 feet thick.

[1] J. S. Diller, Fourteenth Ann. Rept. U. S. Geol. Survey, p. 418. H. W. Turner, Text of the Jackson Geologic Atlas, folio No. 11.

[2] Idem., p. 417.

In Morris Ravine there has been much mining done. The material is similar to that at Cherokee and at the Miocene mine. In addition to the white quartz pebbles, there are also pebbles of the various members of the auriferous slate series, and of andesites apparently of Tertiary age. Pebbles of hornblende-andesite were also seen where the road from Oroville to Pentz crosses a low ridge of the Ione formation which extends westerly from the west end of the South Table Mountain and in Beatson Hollow. In all of these cases, so far as the writer's observations go, these pebbles form a layer directly under the basalt and on top of the Ione formation.

The Spring Valley mine at Cherokee, where hydraulic mining is said to have been invented, has produced more gold than any of the other mines mentioned. It has already been thoroughly described by Whitney and Diller.[1] Petrified wood occurs in this deposit, and bones and teeth of mastodons are said to have been found there.[2]

UPPER CRETACEOUS SANDSTONE.

Cretaceous sandstones of the Chico group undoubtedly underlie much of the volcanic area in the lower foothills from Oroville Table Mountain to the north limit of the sheet. They are extensively exposed in the neighborhood of Pentz, near Mineral Slide on Little Butte Creek, near Centerville on Big Butte Creek, in the canyon of Chico Creek, and doubtless along the creeks farther north. They are everywhere quite unaltered, and are very nearly horizontal, the gentle dip being westerly. The beds in the canyon of Chico were visited in 1885. Fossils were found abundant at a point 7½ (?) miles in an air line from the town of Chico, in a hard, bluish, calcareous layer by a salt lick on the north side of the canyon at the mouth of a ravine draining into Chico Creek from the north. A little farther up the creek on the same side is a better exposure of the fossiliferous beds. It is just at the latter point that the flume of the Sierra Flume & Lumber Company crosses the creek.

On Big Butte Creek, below Helltown, the Chico sandstones have a thickness of perhaps 500 feet, the lower portion containing a large amount of gravel, which is said not to carry a workable quantity of gold.

Lists of the fossils collected in the Chico beds may be found in the writer's previous report.[3]

[1] See Whitney, Auriferous Gravels of the Sierra Nevada, p. 480; Diller, Fourteenth Ann. Rept. U. S. Geol. Survey, p. 418; and the reports of the State Mineralogist of California.

[2] Raymond, Mineral Resources, 1874, p. 133.

[3] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, pp. 458-461.

SUBJACENT SERIES (PRE-CRETACEOUS).

JURATRIAS BEDS (MONTE DE ORO FORMATION.)

In 1886 the writer noted a streak of clay-slate containing some conglomerate by the road to Oregon Gulch, south of Monte de Oro, which forms the south point of the main Table Mountain. The slates looked so little altered that they were examined for fossils, but only a few plant impressions were found. The conglomerate was seen to be made up in part of pebbles (No. 149 Butte Co.) of old andesites (porphyrites). In 1894 Mr. T. W. Stanton visited the locality, and discovered and collected some very good plant remains near the Banner gold quartz mine. Professor Ward examined these plant remains, and expressed the opinion that they are of middle Mesozoic age, and then referred them to Professor Fontaine, whose report is herewith appended:

[*Extract from letter of Prof. William M. Fontaine to Prof. Lester F. Ward, dated April 22, 1895.*]

I have examined carefully the plants from near Oroville, Cal., collected by Stanton and Oliver, with the following results:

1. Perhaps the most common form is a Tæniopteris, which I cannot distinguish from *T. stenoneura*, Schenk, found in the Grenzschichten and in the lower Rhetic of France.

2. Not uncommon is a narrow form which is most probably *Tæniopteris tenuinervis* of the same beds, and which is still more characteristic of the Rhetic.

These narrow Tæniopteris forms are the most abundant imprints among the California fossils. This type goes up, it is true, as far as the Oolite, but in species not seen among these fossils. Macrotæniopteris, if present, must be much rarer than Tæniopteris. I am not sure that any of this type is present. There is one large fragment, poorly preserved, that looks much like a Macrotæniopteris, which resembles *M. magnifolia*. There is a ribbed imprint, an imprint of the inner wall of either an Equisetum or Schizoneura. It looks more like the imprint Schenk calls *Calamites Gumbeli* of the Grensch, which Schimper makes *Equisetum Gumbeli*. There is a very fine plant of *Ctenophyllum grandifolium* of the Richmond coal field, and several fragments of the same plant. This is of great value in fixing the age of the strata, as this type of plant is unmistakable, and is not known except in the uppermost Trias and Rhetic. Schenk's *Pterophyllum carnallianum* is probably a small variety of it. I may say here that a few years ago some Mexican brought a few fossil plants from Mexico, and they were submitted to me. Among them were fine specimens of this Ctenophyllum, and from them I felt sure that uppermost Trias and Rhetic extend into Mexico.

There are several good imprints of a Podozamites which I can not distinguish from *P. Emmonsi* of the N. C. uppermost Trias. Possibly it may be *P. lanceolatus*. If so, it is the Rhetic rather than the Jurassic type of this widely-extended and persistent form of Podozamites. It is now so much expanded by species-makers that it is rather a group-type than a species, like *Pecopteris Whitbiensis*.

There are a number of scattered leaves like Schenk's *Zamites angustifolius* or more probably *Podozamites tenuistrictus* of the Richmond coal.

There is an imperfectly preserved imprint of a very large Danæopsis, probably *Danæopsis marantacea*, another Rhetic plant. It shows the nervation and basal portion of several pinnules attached to the rachis.

There are probably three different ferns, but they are so few and in such small fragments of the terminal portions of ultimate pinnæ, that nothing of their true nature can be made out. It is impossible to say if they are Triassic or Jurassic. They have rather more of a Jurassic than a Triassic facies.

Taking all the evidence, I think it can be positively said that *this flora is not older than the uppermost Trias, and not younger than the Oolite.* I feel pretty sure that it is true Rhetic, somewhat younger than the Los Bronces flora of Newberry, and the Virginia Mesozoic coal strata. It is much like the Rhetic flora of France, made known by Saporta. At any rate, this *is a new grouping of plants that certainly deserves to be carefully collected. I do not think the fossils now in hand suffice to fix narrowly the age, which may be lower Jurassic.*

In 1895 Professor Ward visited this locality and made a much larger collection, although not at precisely the same point where Mr. Stanton collected. This second collection has not yet been studied. The slates of the area are very similar to those of the Mariposa formation, from known areas of which they are, however, widely separated. This plant-bearing series may be called the Monte de Oro formation, from the point so named that lies just north.

CARBONIFEROUS BEDS (CALAVERAS FORMATION).

The limestone carrying Carboniferous fossils east of the road to Magalia and about 2 miles northeast of Pentz was noted in the previous report. This locality was first discovered by the Whitney survey.

In 1894 Mr. T. W. Stanton found a loose piece of sandstone near the Welch hydraulic mine, about 1½ miles east of north from Pentz, in which were impressions of fossil shells. This was referred to Mr. Charles Schuchert, who reported that the fossils were not sufficient for determining the age, but that one of them seemed to be a Meekella, which is known only in the upper Carboniferous.

Just east of the schoolhouse by the road from Pentz to Cherokee is exposed a series of clay-slates with layers of greenstone, which continues to the West Branch of the North Fork, following the road along Cherokee Creek. South of the West Branch are a number of blue limestone croppings, some of which were examined by Mr. Stanton, who found rounded crinoid stems in the limestone just west of the mouth of Cherokee Creek. The localities near the Magalia road northeast of Pentz, without much doubt, are in the clay-slate belt above referred to. At the mouth of Cherokee Creek these slates strike N. 28° W., and dip NE. 70°, but farther southwest the strike is more nearly east and west.

There is some blue limestone on Big Butte Creek above Helltown, and Mr. Diller[1] reports some on Chico Creek 16½ miles northeast of the town of Chico, in which he found crinoidal columns.

The supposed Carboniferous conglomerate noted by the writer in an article in the American Geologist (Vol. XIII, p. 244), to the south of the Monte de Oro, is part of the clay-slate belt containing Juratrias plant remains described previously, and is therefore of Juratrias age.

[1] Bull. U. S. Geol. Survey No. 33, p. 11.

GRANITE AND QUARTZ-DIORITE.

A rock of the granite series forms a considerable area about the Spring Valley reservoir at Concow.

The walls of the canyon of the West Branch of the North Fork of the Feather below the bridge of the road to Kimshew, in the northeast part of the Chico sheet area, are made up of a coarse-grained granitoid rock which the microscope shows to be a quartz-diorite. In general both the feldspar and the green hornblende show an idiomorphic tendency, the quartz being interstitial and the last element to crystallize.

The quartz-diorite is variable in appearance and texture, some of it being quite dark and fine grained, and this portion, so far as examined, contains little quartz. This finer-grained diorite may be the older and may occur as inclusions in the coarse quartz-diorite, but at some points there seemed to be a gradation between the two rocks. That the rock has undergone compression may be seen at many points, the abundant fractures and slickensided surfaces along seams being evidence in this direction, and the microscope shows the rock to have been much crushed, a part of the quartz being broken up into a mosaic. About one-fourth of a mile below the bridge of the Kimshew road the diorite contains abundant minute veins, some of quartz, others appearing to be made up of epidote, quartz, and feldspar. These veinlets are more or less roughly parallel, forming two or more systems, but some are irregular and referable to no distinct system. The croppings viewed as a whole are full of partings, one set having a strike about west of north, and another nearly horizontal, while other fissures cut these systems at varying angles, resulting in the rock being broken up into polyhedrons of varying shape and size. No portion of this diorite area was seen in which there was not some evidence of fracturing. The area extends south to near Flea Valley, in the area of the Bidwell Bar sheet.

SODA-GRANULITE OR APLITE.

On the road from Cherokee Creek, about 2 miles south of Yankee Hill, by the pipe of the Spring Valley ditch, is a dike of a coarse greenish-white granitoid rock (No. 774), apparently made up wholly of quartz, white feldspar, and greenish grains. The feldspar in the specimen collected is too decomposed to determine satisfactorily, but from the close resemblance of this dike to certain dikes in serpentine in Plumas County the feldspar is thought to be albite. The greenish grains are seen under the microscope to be chlorite.

SERPENTINE.

There are considerable masses of this rock to the east of Magalia, along the West Branch of the North Fork and on the ridge east of Saw Mill Peak. There is also some west of Yankee Hill and at Nelson Bar.

Four miles northeast of Oregon City, just east of an old dry reservoir, is a dike of serpentine, a thin section of which (No. 540 S. N.) shows abundant remains of monoclinic pyroxene, giving evidence that the original rock belonged to the peridotite family.

GREENSTONE SCHIST SERIES.

These rocks are chiefly exposed in the southeast portion of the area. As before noted, the occurrence to the south of Oroville Table Mountain of slates (Monte de Oro formation) containing plant remains of Juratrias age interbedded in these tuffs shows that part of them are of that age, while the same relation of the greenstone tuffs along Cherokee Creek to the Carboniferous beds there indicates a Paleozoic age for part of them. The greenstone schists of the Chico sheet area are quite the same in appearance and composition as those described in the Smartsville and other folios of the foothill region. An examination of a number of thin sections shows the rocks to have been largely andesitic tuffs, with some layers that may represent massive flows of andesite and basalt. Epidote, uralite, chlorite, and secondary feldspar are usually present in these altered rocks, and the original constituents in many cases can not be determined specifically. Augite is as often left unaltered as is the feldspar. A considerable part of the greenstone shows its fragmental character, plainly containing angular and rounded fragments of augitic lavas. The general schistose character of the greenstone schists and the bent and fractured feldspars, seen in thin sections, give evidence that these rocks owe their altered condition in part to dynamometamorphism.

Nearly all the rocks of this greenstone series belong to the group of augite-porphyrites of Rosenbusch. They may also be called schistose apo-andesites and apo-basalts.

GOLD-QUARTZ MINES.

In the black clay slate of Juratrias age, south of Monte de Oro, is the Banner gold-quartz mine.

In the greenstone schists to the east of Table Mountain quartz veins occur at several points and have been mined with varying success. There are also some quartz veins that have been worked for gold farther north, near Magalia and Inskip.

CHAPTER III.

THE BIDWELL BAR AREA.

This district extends from the foothills in the southwest corner, with an elevation in the canyon of the Feather River of only 200 feet, to the considerable ridges of the north portion of the area, one point, Bucks Mountain, having an elevation of 7,231 feet. The region is well wooded, and much of it is covered with thick brush, making exploration difficult. The river canyons are in general very rugged and deep, and in places impassable. There are few grander canyons in the Sierra Nevada than that of the North Fork of the Feather just west of Bucks Mountain, where it is about 5,200 feet deep, as measured from the top of the mountain, and about 4,300 feet deep as measured from the top of the high plateau to the west of the canyon, along the fortieth parallel. Some of the scenery is very picturesque, and there are a number of waterfalls, not exceeded in beauty by any others in the State. One of these is on Camp Creek, shortly before it joins the North Fork of the Feather, and about 2 miles above Big Bar.

A portion of the canyon of the Middle Fork of the Feather, where it is bounded by bare granite walls, is known as Bald Rock Canyon, and about 2 miles downstream from the point called Bald Rock, a stream known as Fall River joins the Middle Fork. About 1 mile above its mouth this stream leaps over a cliff perhaps 450 feet in height, forming a beautiful fall, below which is a series of cascades.

The granite of the amphitheater about the base of the falls is much shattered, many of the fissures formed being nearly vertical, and this zone of fracturing has probably been the primary cause of the formation of the cliff over which the water pours. These falls are well worth a visit, but are at present difficult of access.

There are also some picturesque cascades on Powell Creek, a branch of the South Fork of the Feather, and a small fall of considerable beauty on another branch of the South Fork near the road from Lumpkin to Little Grass Valley. The water here falls over a bluff of the older basalt. The point is about 7½ miles northeast of Lumpkin.

The region as a whole is characterized by the great predominance of igneous rocks of various ages, from Paleozoic to Tertiary. About one-half of the area of the sheet is occupied by granitic rocks, more than one-fourth by basic igneous rocks and schists derived therefrom, and about one-sixteenth by the Tertiary igneous rocks, leaving only about three-sixteenths of the area for the sedimentary terranes, and these contain at some points abundant igneous dikes.

FAULTING AND LANDSLIDES.

On the steep slopes of the canyons one may often note benches, which appear to have been formed by landslides. They may be seen along the new lower road to Forbestown from Robinson Mill, where there are slight depressions in the benches, which after rains contain water.

A considerable landslide or fault appears to have occurred on the northwest slope of Bloomer Hill. There is a high northwest spur with gentle top slope extending more than a mile from the summit of the hill, and on the north side of the northwest end of this spur is a precipitous face perhaps 400 feet high, the dropped-down area to the north forming an irregular series of flats, on which the old road to Island Bar runs.

A still better example of a post-Tertiary displacement may be seen to the west of the head of Dogwood Creek. This fault scarp is shown in Pl. XX. The wooded flat lying below and to the east of this scarp appears to represent a downthrown area, and the probability of this is heightened by the occurrence of Tertiary river gravels and lavas on this area and their recurrence on the top of the ridge to the west of the fault scarp.

Meadow Valley seems likewise to represent a depressed area, with a zone of faulting along the east side of the Spanish Peak ridge. The Tertiary andesitic tuffs to the north and south of Meadow Valley continue down to the level of the valley; and similar tuffs overlying river gravel cap the Spanish Peak ridge, 3,000 feet vertically above the valley. This displacement appears to have taken place after the last andesitic eruptions, either at the end of the Tertiary or early in the Pleistocene, for the valley was the bed of a lake during a part of Pleistocene time. The broad plateau 7 miles southeast of Spanish Peak likewise may be regarded as a downthrown block, and the steep slope west of Bear Creek a zone of faulting. There are river gravels on this plateau, which is mainly covered by andesitic tuffs. That the underlying surface of the older rocks is likewise nearly level may be seen from the level line of contact between this old surface and the overlying volcanic material, as shown on the geologic map. The displacement of this plateau is thought to be comparatively slight. There is evidence of faulting along the Diadem lode at Edmanton, 2½ miles southeast of Spanish Peak, and this is in the same general fault zone as that along Dogwood and Bear creeks and the east slope of Spanish Peak.

There is a body of gravel directly overlying the Diadem lode. Professor Pettee[1] writes concerning this locality:

> Since the deposition of this gravel there has been a fault or slip in the bed rock amounting to at least 6 feet. The fault is traced up through the gravel by means of clayey slickensides, the surface of which is smooth, and striated with parallel lines. That this really marks the place of a crevice in the gravel is further shown

[1] Auriferous Gravels of the Sierra Nevada, p. 477.

by the presence of rootlets of trees to a depth of 25 feet below the surface of the ground, a depth several times greater than that to which these rootlets make their way in the undisturbed gravel. The strike of the fault or slope corresponds very closely with that of the bed rock.

In 1894 the writer visited the Diadem lode, which has been much exploited since the visit of Professor Pettee in 1879, and was informed by Mr. Edman that some of the gravel was carried down 40 feet by a fault, and was found in running a drift. He also said that at a point on the opposite side of the ravine there is some similar gravel 120 feet higher than that above referred to. He thinks that there has been a series of faults at this place.

In the bed of the Middle Fork of the Feather River, just above the mouth of Onion Valley Creek, the Paleozoic clay-slates are cut by numerous dikes. One of these was noted which had been faulted, the displacement amounting to about 15 inches. Careful observations will probably show that similar small faults are to be found at many points. The same sort of evidence may be noted under the microscope in thin sections. The faulting is particularly well shown in crushed rocks in which there are triclinic feldspars showing lamellar twinning.

Along the Feather River above the mouth of Onion Valley Creek may also be noted a joint system which divides the slates into blocks of rhombohedral shape. This system of fissures appears to have formed subsequent to the slaty cleavage, and is clearly explained by Dr. G. F. Becker in his paper "On the structure of a portion of the Sierra Nevada."[1]

Professor Pettee also notes faults in the bed rock of the Brandy City[2] gravel deposit, and at Gopher Hill.[3]

SCHISTOSITY AND BEDDING.

The sedimentary rocks in the Bidwell Bar area are chiefly argillite, mica-schist, and quartzite, with limestone lenses, and the original bedding, where it can be often determined, coincides roughly with the planes of schistosity developed later. However, a careful study of the area would probably show minor discordances abundantly. The hornblende schists are chiefly altered augitic tuffs, but considerable streaks of the talc schists were without doubt formed from basic massive igneous rocks of the peridotite group, in which pyroxene is a prominent constituent.

A very interesting phenomenon of structure is shown in fig. 19. The schistosity represented by the broken lines is nearly everywhere parallel to the granite contact. In this respect the region represents a striking similarity to the Rainy Lake district described by Lawson,[4] and which is particularly well brought out on the geological map that accompanies his monograph.

[1] Bull. Geol. Soc. America, Vol. 11, pp. 49-74.

[2] Auriferous Gravels, p. 461.

[3] Idem, p. 473.

[4] The geology of the Rainy Lake region: Ann. Rept. Canadian Geol. Survey, 1887 Part F

FAULT SCARP AT THE HEAD OF DOGWOOD CREEK.

Professor Lawson writes (p. 142):

An important discovery has been made in the mapping of the relative distribution of the upper and lower Archean, whereby it appears that the latter, consisting of Laurentian gneiss and granite, occurs in large isolated central areas more or less completely surrounded by the schists of the upper Archean (now called Algonkian), the encircling belts anastomosing and forming a continuous meshwork.

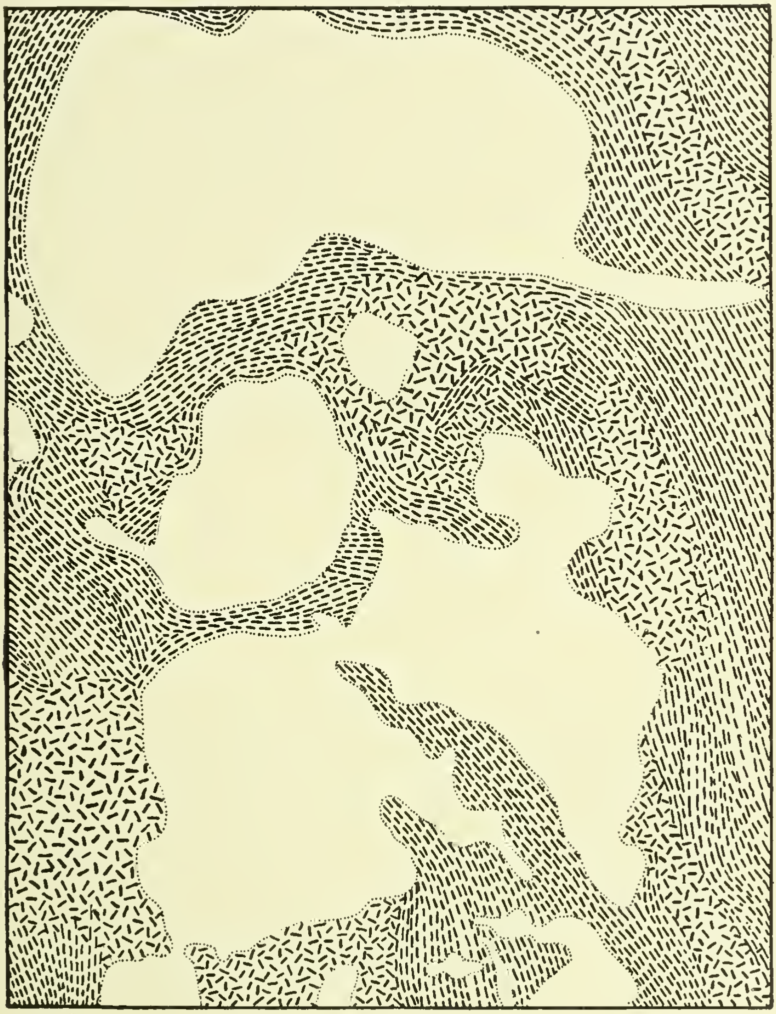

FIG. 19.—Diagrammatic map of the massive and schistose rocks of the Bidwell Bar area, showing the manner in which the lines of schistosity are, as a rule, parallel to the contact of the massive granite areas, which are represented in white without hachures.

Van Hise[1] writes in regard to this phenomenon:

These relations are taken to mean that the surrounding schistose rocks represent sedimentary beds which have been thrust aside by the entering granite. Along the contacts of the Laurentian (Archean) and the Coutchiching (Algonkian) are found such minerals as andalusite, staurolite, and garnet.[2]

[1] Bull. U. S. Geol. Survey No. 86, p. 67.

[2] Indicating contact metamorphism.—H. W. T.

The similarity of the two districts goes further than the structure, for in addition to the granite there are considerable serpentine masses, and belts of hornblende schists, with minor amounts of true sediments. Though differing widely in age, some of the sediments of the Bidwell Bar area being certainly Carboniferous, in both areas more or less similar igneous rocks form the bulk of the districts.

There is also some similarity as to structure with certain areas in the Black Hills, as described by Professor Van Hise.[1] Surrounding central granite masses there are in the Black Hills concentric layers of schists. These appear to have been formed as a result of pressure which at any given point appears to have been normal to the periphery of the granite, which is intrusive in and later than the schist series (Algonkian), so that the planes of schistosity are parallel to the granite contact, and frequently at right angles to a previously developed slaty cleavage.

Schists formed in this way as a result of pressure acting normal to the contact of the intrusive masses, are believed to exist in the Bidwell Bar area in minor amount only. In general the cleavage of the schistose rocks appears to antedate the period, known to be in part late Jurassic or early Cretaceous, of the intrusion of the most abundant granitoid rocks (quartz-mica diorites and gabbros). The most marked effect of these Juratrias intrusions is the formation of pronounced zones of contact metamorphism.

THE SUPERJACENT (TERTIARY AND PLEISTOCENE) SEDIMENTARY FORMATIONS.

PLEISTOCENE RIVER GRAVELS.

The old river gravels found above high-water level, chiefly at the bends of the streams, are referred to the Pleistocene period. Such are the deposits at Bidwell Bar and those along the South Fork of the Feather near Stringtown, at Island Bar, Hamilton Bar, and Big Bar on the North Fork, and at Hartman Bar and Butte Bar on the Middle Fork. In fact, there is scarcely a stream of any size in the area along which such bars may not be found. Some of them are still being mined for gold.

Just east of the mouth of a branch of the North Fork of the Yuba, called Slate Creek, is a nearly level-bottomed ravine, separated from the creek by a hill. This ravine is called the Race Track, and investigation showed it to be a bit of a former bed of the creek. The gravel of this former channel is still being mined for gold.

PLEISTOCENE LAKE GRAVELS.

The gravel beds about Meadow Valley, as may be seen by referring to the geologic map, underlie the valley and form terraces about it, some of which attain an altitude of more than 4,000 feet, the lowest

[1] Bull. Geol. Soc. America, Vol. 1, pp. 203-244

part of the valley having an altitude of about 3,700 feet.[1] As has been before intimated, this valley appears to have been formed by orographic causes, probably in early Pleistocene time. The gravel beds that form the terraces about it plainly show that it was occupied for a long time by a body of water, and a glance at the topography shows that this lake must have drained easterly—that is, into the American Valley, itself an old lake bed, although apparently a shallow one.

The Meadow Valley gravels have been mined very extensively by the hydraulic method at Gopher Hill, 1¼ miles east of Spanish Ranch. The banks now exposed show the character of the material finely. The exposure on the south side of the flume shows a vertical bank about 150 high in which are two layers of a light-buff color from 1 to 5 feet in thickness. The lower layer is perhaps from 40 to 60 feet above the bed rock, and the upper layer 50 feet higher. The same material is exposed in a bank north of the flume, and a specimen was taken there. Microscopic examination shows this to be composed of isotropic, translucent grains, often reddish by discoloration, and doubly refracting grains and angular particles, some of which are probably quartz. The isotropic material is probably volcanic glass. A partial chemical analysis of the specimen (No. 711 S. N.), by Dr. H. N. Stokes, is given herewith:

Analysis of volcanic layer from Gopher Hill gravels.

	Per cent.
Silica	41.84
Potassa	.32
Soda	.28

This analysis does not appear to suggest a volcanic origin more than any other, but the presence of the glass particles shows that these layers may represent in part volcanic ashes, perhaps from the Lassen Peak volcanic vents. The material is very light and friable.

The general color of the Gopher Hill gravel is reddish, a dark red near the surface. The pebbles are usually small, from 1 to 4 inches in diameter, and by far the greater number of them are flattened. Decomposed lava pebbles were noted, but the pebbles are mostly composed of rocks of the pre-Tertiary formations, quartzite, greenstone, and siliceous argillite being represented. Pebbles of white quartz occur, but are not abundant. There is a large amount of silt and sand, perhaps one-half of the entire material. Lying about over the area that had been washed by the hydraulic method were noted many well-worn pebbles about a foot in diameter, but there were very few of these to be seen in place in the banks.

[1] Am. Geologist, Vol. XIII, p. 243.

A large surface of the lower gravel beds at Grub Flat and vicinity has been mined over. Underlying the well-rounded gravel to the northwest of Grub Flat is some decomposed "cement" gravel, made up largely of small round red, brown, and white particles between which there has been an opaque white secondary substance deposited in concentric layers (No. 709 S. N.). Under the microscope this is seen to be a distinct tuff, but decomposed. It is made up of microlitic and glassy fragments in which the outlines of the feldspars are still to be seen. Some fragments contain fresh augite and hornblende grains, and there are also grains of serpentine present. Some of the particles are thoroughly rounded.

Along Wapansie (spelled also Waponseh) Creek some of the lake gravel is subangular. Three and a half miles east of Meadow Valley post-office, on a branch of Slate Creek, at an altitude of over 4,000 feet, is some gravel, with angular blocks of the late doleritic basalt like that capping Clermont Hill. Four miles southeast of Meadow Valley post-office, on the ridge west of Deer Creek, is some Pleistocene gravel reaching an altitude of 4,700 feet, and a gravel area west of the South Fork of Rock Creek attains an altitude of 4,500 feet. There are also gravel beds that have been mined by the hydraulic method on the ridges east and west of Whitlock Ravine. These gravels are like those at Gopher Hill. There is little doubt that all of these isolated gravel patches were originally connected with the large Meadow Valley area of lake gravel, although some of them may have been formed by Pleistocene streams draining into the lake, and some of them may have attained their present altitude by displacement subsequent to the lake period. The rocky barrier between Meadow Valley and the American Valley has been cut through by Spanish Creek in late Pleistocene time, and thus the lake was drained.

That the gravel beds about Meadow Valley are a lake deposit was first stated, so far as known to the writer, in an interesting report on this district in 1867 by J. A. Edman,[1] from which the following extracts are taken:

On the flats near Meadow Valley the surface gravel rests on tufa-beds of undoubted volcanic origin (andesitic tuff), being of an ashy gray color and containing much pumice. These characteristics generally pertain to that portion of the basin south of Meadow Valley Creek.

The evidence of the geology and present topography points to the probability that the Meadow Valley basin contains a lacustrine deposit, principally made by a large stream entering the basin from the northwest,[2] and having its outlet at some point to the southwest, near upper Rock Creek or Slate Creek. * * *

[1] Raymond, Mineral Resources, 1876, pp. 120-121, 123.

[2] The gravels that were regarded by Mr. Edman as evidence of a stream entering from the northwest are in part the white quartz gravels, and are undoubtedly older than the lake beds, but in the main Mr. Edman's report may be regarded as a very remarkable one, considering how little the geology of the Sierra Nevada was understood at the time of its publication. On his geological map of the underlying formations (the bed-rock series) he clearly perceived the difference between the green stone schists, the clay slates, and the serpentine, and his areas correspond roughly with those outlined nearly thirty years later, with all the advantage of good maps and the increase of geologic information since that time.

Two basins among the hills, known as Snake Lake and Smiths Lake, show recent alluvial deposits on the site of former lakes where but small ponds now remain. The level surface of the former, about 200 acres in extent, consists of pure vegetable mold to some depth, resting on sandy clays and beds of loose gravel.

That Mr. Edman perceived the late age of the Meadow Valley deposits may be seen in the first quotation, and Professor Pettee found other evidence in the same direction in 1879.[1] The reader should refer to their reports for full information. As may be seen by examination of the geologic map, the writer regards the Smith Lake deposit as part of the Pleistocene Meadow Valley gravel.

EVIDENCES OF GLACIAL ACTION.

It is again to the report of Mr. Edman that we turn for the first published evidence of the former existence of glaciers in the Bidwell Bar area. Mr. Edman points out (p. 111) that there are evidences of glacial action on the slopes of Spanish Peak ridge, although the accumulations are much smaller than at other localities. These moraines are noted on the geologic map. Between these deposits and the steep north slope of the granite ridge are several small but picturesque lakes. On the north slope of Bucks Mountain ridge are moraines and morainal lakes, and at a point about 2 miles southeast of the summit is a little lake or pond that has been formed by a terminal moraine. The moraines to the west of Haskells Valley are on the north slope of the serpentine ridge of which Grizzly Hill is the highest point. The road from the Buckeye House to Spanish Ranch passes over some of this glacial débris.

Polish was noted on the rock of this north slope, and some scratched bowlders were found in the morainal material. Some granitic bowlders were seen here on the serpentine in very perplexing situations if regarded as transported by ice, since there is no granite about the névé region of this former glacier. On close examination, however, this granite was found to contain muscovite and to be unlike that of any of the large granite areas of the district. A more careful search showed that these granitic bowlders had weathered out from dikes in the serpentine, and are not far from in place. These dikes are in fact soda-granulites or aplites, and are briefly described under that head.

The elevation of the serpentine ridge just south of this morainal area is only about 6,000 feet, and this is remarkable as being the lowest elevation in the Sierra Nevada, so far as the writer's observations go, that sheltered a glacier during the Glacial epoch. The extremely steep north slope of this ridge is evidently the explanation of the former accumulation of ice at this point.

On the east slope of the Dogwood Peak ridge, about 1½ miles southeast of the peak, is a small bank of loose material, apparently a terminal moraine. It lies about 500 feet below the top of the ridge. At the head of the ravine which contains this moraine there was a bank of

[1] Auriferous Gravels, pp. 472–478.

snow in August, 1894. The rocks below the snow bank were smoothed, but no striæ were noted. The elevation of the ridge top is more than 6,000 feet. As a general rule, it may be said that in the Sierra Nevada all those slopes which shelter snow banks during the entire season nourished glaciers during the Glacial period.

On the high plateau of the northwest section of the district to the west of the North Fork of the Feather River is another glaciated region. There is more or less morainal material scattered over nearly the whole of this plateau, and definite moraines are to be seen at the head of Chambers Creek, near the mouth of North Valley Creek, and about Crane Valley. The granite of the drainage above (north of) Crane Valley is finely polished and grooved in places.

There are also extensive moraines south of Table Mountain at the head of Little Kimshew Creek. These materials, which contain water-worn pebbles, have been mined for many years for the gold they contain. The camp was formerly known as Little Kimshew. Snow's mine, 1½ miles south of Table Mountain, is still being operated. This mine is further referred to under the heading "River gravels." Morainal deposits were formerly extensively washed for gold at Big Kimshew, 2½ miles southwest of Table Mountain, and at a point east of Rock Creek, by the trail from North Valley to Lotts Diggings. Some morainal material was also being mined for gold at the time of my visit (1894) at a point 4¾ miles due east of Table Mountain.

At North Valley, and at several points to the southwest of the valley, by the trail, are patches of well-worn gravel. These deposits may have been formerly continuous, and may have been formed by the damming of the waters of North Creek by a moraine, which it has since cut through. Pebbles of granitoid rocks, pyroxenite (?), and of amphibolite were noted in these deposits, and in addition rounded fragments of the Tertiary olivine basalt and porphyritic basalt of the ridge to the north. The amphibolite pebbles presumably came from near the Campbell Lakes.

NEOCENE RIVER GRAVELS.

It is safe to assert that in Neocene time, as now, an extensive system of rivers existed in this area. The great subsequent erosion, however, has removed the greater part of the gravels formed by them, and the preservation of many of the remnants of these old channels is due to their being capped with volcanic material, which flooded the river valleys during and at the close of the Tertiary period. As may be seen by referring to a paper by Ross E. Browne on "The ancient river beds of the Forest Hill divide,"[1] and others by Mr. W. Lindgren and the writer,[2] the Neocene Auriferous gravels of the Sierra Nevada can be

[1] Tenth Ann. Rept. State Mineralogist of California, pp. 435-465. Browne's third period includes the Pleistocene gravels.

[2] W. Lindgren, Two Neocene rivers of California Bull. Geol. Soc. America, Vol. IV. H. W. Turner Fourteenth Ann. Rept. U. S. Geol. Survey, p. 465, and Am. Geologist, Vol. XV, 1895, p. 371.

divided into two main groups, those of the first period, composed chiefly of white quartz pebbles and light-colored clays and sands, with minor lava flows of rhyolite; and those of the second period, called by Browne the period of the "volcanic cement" (andesite-tuff) flows. The former gravels are free from volcanic pebbles; the latter often contain them in abundance. The larger part of the auriferous gravels belong to the first period. The writer has also suggested the recognition of an intermediate period. The pebbles of the gravel deposits of this period are chiefly of the pre-Cretaceous sedimentary and igneous rocks, and are usually dark in color; such gravel is frequently called "bull or bastard gravel" by the miners, and it is often less auriferous than the white quartz gravel and is not always of economic importance. An attempt will be made to group the occurrences under these three periods.

THE OLDER WHITE QUARTZ GRAVELS.

The great channel from Scales, Sierra County, is preserved at Union Hill, at Council Hill, and at Brandy City, in the southeast corner of the Bidwell Bar area, and has been found to be rich in gold at most points mined. For full details as to this old channel, which has been traced into Yuba County, the reader is referred to the report by Professor Pettee in Whitney's Auriferous Gravels. The Brandy City channel is capped with andesitic tuffs and breccias. There is white quartz gravel also at the American House, on the road from Strawberry Valley to Laporte. This is not covered with lava, although there is an area of basalt immediately to the east. The abundance of white quartz veins near the gravel suggests a local origin for a portion of this quartz gravel.

At the head of Dogwood Creek, to the east of the fault scarp before noted, is some river gravel capped by the older black basalt. The camp was known as the Sweet Oil Diggings, according to a resident of Plumas County. Some of the gravel from a shaft sunk through the basalt was examined. Most of the pebbles are of white quartz, but there are also some of quartzite, siliceous argillite, and a variegated breccia (No. 94 S. N.) which has been noted by the writer in many gravel deposits in Plumas County. These breccia pebbles may have come from some Juratrias beds called the Milton formation,[1] and may be of use in tracing out the former course of the channels of Plumas County, as they occur in many of the deposits.

Three and one-half miles southwest of Franklin Hill is a remnant of a gravel channel that has been mined by the hydraulic method. The writer's notes contain no description of the kind of pebbles here. It lies at the edge of an area of the older basalt. Some white quartz gravel has been exposed in shallow shafts about $1\frac{3}{4}$ miles southwest of Franklin Hill, near the road. These two deposits on Franklin Hill

[1] Am. Geologist, Vol. XIII, p. 233.

ridge may easily have been connected at one time with the Sweet Oil Channel if, as has been suggested, there is a fault at the head of Dogwood Creek, but it is also not unlikely that the Sweet Oil Channel represents a part of the same Neocene river as the white quartz gravels underlying Little Grass Valley. At Davis Point, by a ravine draining into Fall River from the south, about 1½ miles southeast of Cannel Peak, there is gravel composed mostly of white quartz pebbles, but with some volcanic pebbles also. The bed rock is hornblende schist. The place was visited by Pettee.[1] This gravel was hydraulicked.

NEOCENE RIVER GRAVELS OF THE INTERMEDIATE PERIOD.

The Dodson gravel mine lies about 3¼ miles northwesterly from Strawberry Valley, at the south border of the basalt flow that caps the Mooreville Ridge. The gravel is from 30 to 100 feet thick and is largely coarse, but there is fine material in places. The pebbles are of granite, andesite, basalt, quartz, and metamorphic rocks. They vary in size from small pebbles to large bowlders, all well waterworn. A considerable amount of finely preserved silicified wood is found here. Professor Knowlton determined this as being coniferous wood (Araucarioxylon). The basalt capping the mine is from 15 to 30 feet thick, and shows a columnar structure in places. Some of the basalt pebbles contain crystals of chabazite in cavities. The bed rock is granite. Ludlam's hydraulic mine is, without much doubt, on the same channel as the Dodson. It lies on the north edge of the basalt of the Mooreville Ridge, about 4 miles a little west of north from Strawberry Valley. It differs in no essential particulars from the Dodson mine. The bed rock is granite. The gravel attains a thickness of about 90 feet, and the basalt capping a thickness of about 150 feet. The lower gravel is chiefly made up of the older sedimentary and associated igneous rocks of the Auriferous slate series, and the upper part of Tertiary lavas. Fine silicified wood occurs here also. There is gravel on the Mooreville Ridge 2 miles northeast of Ludlam's mine. Under the basalt of Kanaka Peak there are well-rounded pebbles of the kind noted at the Dodson mine. At Walker Plain there are gravel beds under the basalt. The gravel of this channel at the Buckeye House is much like that at Kanaka Peak and the Dodson mine, so far as examined. While it is not probable that all of the gravel deposits under the older basalt belong to the same period, most of them are similar in containing some pebbles of Tertiary volcanic rocks and of the older rocks of the Auriferous slate series and without doubt were formed by rivers of later age than those of the white quartz gravel period.

The area of "bastard" gravel about three-fourths of a mile north of Lexington Hill, by the road to Little Grass Valley, appears to rest in part on andesitic tuff. Greenstone schists occur immediately to the south, but to the north there is nothing but andesitic ash. A shaft 20

[1] Auriferous Gravels, p. 469.

feet or more deep, sunk just north of the gravel, penetrated only the andesite. The andesitic ash area continues down the slope 400 feet vertically to Little Grass Valley. This gravel may therefore be supposed to belong to Browne's volcanic period, although the case is not a clear one and the gravel is similar to that of the intermediate period. Pebbles of quartzite, siliceous argillite, quartz porphyry, a few of vein quartz, and one soft white pebble of a Tertiary-looking rock (No. 656) were observed in this gravel. The white pebble contains a good deal of infiltrated silica, both chalcedonic and crystallized. A microscopic examination shows it to be fragmental, and to contain untwinned feldspars that strongly resemble sanidine. It appears to be an altered rhyolite-tuff.

On the east slope of Cammel Peak there is a little gravel. The same variegated breccia before noted at other gravel deposits is represented among the pebbles.

On the summit of the ridge south of the Middle Fork of the Feather River, at a point about 2 miles north of Lava Cap, is a small area of river gravel. This was at one time covered with the older basalt, a remnant of which still remains (No. 50 Plumas). There is a considerable variety of pebbles, two kinds of which have been determined by the use of the microscope. These (No. 78 and 79 Plumas) are hypersthene-andesite and apo-hornblende-dacite. Pebbles of quartz-porphyry, granite, and various metamorphic rocks were also noted.

The Spanish Peak gravel channel has been described by Professor Whitney,[1] in part from data furnished by Mr. Edman. Mr. Diller visited the Monte Cristo mine, at the south end of the deposit, and obtained there some leaves of fossil plants, a list of which is given in the writer's former report. Mr. Diller also obtained a small fossil fish from Mr. J. G. Phelps, who found it in the Monte Cristo mine. This was examined by Dr. W. H. Dall,[2] who reported that "the opinion may be expressed with some confidence that the fish was not marine and that it was related to Uranidea." Later the writer collected a few leaves which were referred to Professor Knowlton,[3] who reports as follows: "These leaves all belong to a single species, *Laurus salicifolia* Lx. This species was originally described from Corral Hollow, and has not before been detected at the Monte Cristo mine so far as I know." The lower gravel at the Monte Cristo mine contains a variety of pebbles, with fragments of the older basalt, but no waterworn pebbles of this rock were noted. Among the well-rounded pebbles were some of the variegated breccia of the Milton formation (467 Plumas), noted as occurring at the head of Dogwood Creek. Pebbles of pyroxene-andesite (469 Plumas) also were found. Scattered over the level top of Spanish Peak itself are abundant waterworn pebbles, including many of white quartz. The Spanish Peak ridge deposit is also exposed

[1] Auriferous Gravels, p. 216.
[2] Eighth Ann. Rept. U. S. Geol. Survey, p. 418, footnote.
[3] Am. Geologist, Vol. XV, p. 377.

1½ miles west of Spanish Peak, and pebbles of metamorphic and igneous rocks were noted at numerous places in the andesitic agglomerate and breccia that caps the channel.

Two miles south of the Monte Cristo mine, on the ridge south of Bucks Creek, is a mass of gravel associated with andesitic tuff. There is also a little of the older basalt in place here. The gravels are in general like those at Monte Cristo mine. Pebbles of siliceous metamorphic rocks, of greenstone, of the variegated breccia, and of andesite were noted. There were also fragments of the older basalt, and bowlders and fragments of andesite. At one point a shaft had been sunk through andesitic tuff and struck fine white quartz gravel, some of which lay on the dump. The pebbles of the gravel flat 6 miles southeast of Spanish Peak, on the plateau east of the head of Bear Creek, are mostly of quartzite and other siliceous rocks. Overlying this is andesite-breccia.

About 3 miles south of Grizzly Hill, and north of the point called Gravel Range on the topographic map, well-worn pebbles were noted scattered along the ridge, testifying to the former existence of a river deposit there. Another similar occurrence is at Mullen's farm, on the Big Bend mountain ridge about 1 mile north of the abandoned camp of Big Bend. Pebbles are said to be scattered along the ridge for three-fourths of a mile east of the farm. Those seen by the writer had been picked up on the farm by Mr. Mullen. They were well waterworn and composed of quartz-diorite and greenstone and were from 3 to 6 inches in maximum diameter. Some were flattened and others oblong. Two of these pebbles had grooves on one side, like stones used by Indians in making arrows, according to Mr. Mullen. The possibility suggests itself, therefore, that all of the pebbles may have been brought here by the Indians. A piece of a stone mortar was also seen.

At the point called Clipper Mill, on the road to Strawberry Valley, is a long streak of Neocene river gravel about 600 feet wide. The pebbles are chiefly of the older siliceous rocks. There is no volcanic material associated with this area. At the west end of the andesite-breccia area, or about 1¾ miles east of Clipper Mill, is a small deposit of gravel, known as the Pratt drift mine. About 1½ miles north of Clipper Mill is the Gentle Anna drift gravel mine. The tunnel had evidently cut the olivine basalt that caps the deposit before it struck the gravel, which is half rounded and does not appear to represent a large channel.

The high plateau of the northwest corner of the district, about Table Mountain and the Campbell Lakes, is known locally as Gravel Range, from the occurrence of gravel at numerous points. Some of the so-called gravel is merely morainal material and has been noted under the heading, Evidence of glacial action. The white quartz gravel at Lotts Diggings, just to the north of the fortieth parallel, is undoubtedly a remnant of the oldest river system of this plateau. Like the gravel at Lotts Diggings the other river gravels are at nearly all points capped by the olivine basalt, which appears to be part of the same extensive flow forming the bluffs on the north side of Chipps Creek (Lassen Peak folio). The Butte King and Butte Queen mines belong to this series, but they are north of the area of the Bidwell Bar sheet.

The Reese & Jones drift gravel mine is under a spur of olivine basalt 1½ miles northwest of Table Mountain. The gravel appears to be a part of a thin sheet spread over the ground at the time the basalt flow took place. Some of the gravel is well rounded, but there is also a good deal of subangular material of local origin. Rather abundant are pebbles of hematite, and of chromic iron. The basalt sometimes lies immediately on the bed rock, cutting off the gravel. Mr. Diller, who also visited this locality, kindly furnished me the following notes:

The Butte King, Butte Queen, Bracken, Gregory, and the Jones Bros. (Reese & Jones) mines are all apparently on the same stream or channel. From Butte King to Jones Bros. mine is about 1½ miles in a nearly due south direction. Jones Bros. mine is said to be 300 feet lower, but I think that is too much. The grade of the bed rock is south, and the miners think the stream flowed that way, but without any other reason than the grade. All the mines are much alike, and the mass of the material mined is not clear-washed gravel. To look at the material brought out, one would not suspect that it is gravel, at any of the mines. It is angular and mixed with earth, just like slope talus, and yet in the mines in place, as well as on the dump and elsewhere, much clearly washed gravel is found mixed with the angular material.

The stream was evidently small and most of the fragments are of local rock. Good-sized, well-rounded, and bumped waterworn bowlders, 4 to 14 inches in diameter, are quite common. I did not see any granite bowlders. Most of the waterworn ones are of quartz, quartzite, and dark siliceous metamorphic rocks. The most significant pebbles to the miners are little iron stones. These are well waterworn and brown and heavy. Some of them appear to be brown hematite. Small quartz pebbles are not uncommon, but they are not all well waterworn. The rim rock, they say, is well defined, and the gravel certainly does run out to an edge on both sides. The bottom of the stream is quite regular, but occasionally it rises to the lava. In the Jones Bros. mine a little dome rose in the channel and cut off the gravel, but they continued through and found gravel beyond. At Jones Bros. mine there is about $8 in gold to a small car load of the gravel, and at the Gregory about $2. The Butte King formerly paid $5 to the car, but was very expensive to work on account of water. The Butte Queen, owned by the same company, is working in the opposite direction, and is designed to tap the same channel.

The material mined at Snow's gravel mine was described under the section on glaciers as being moranial, but there is also some river gravel here, well exposed at a hydraulic washing, located at about the point where the house is shown on the map.[1] The altitude of the house, according to the maps, is about 5,200 feet. Here may be seen the mouths of tunnels which have been run in on the channel toward Table Mountain. At the base of the exposure at the hydraulic washing are about 20 feet of sand and well-washed gravel. The pebbles of the bottom part of this were of chert, hornblende schist, slate, granite, and quartz. Overlying the well-worn gravel and sand is a mass of volcanic

[1]The houses of the miners are perhaps one-half mile southeasterly from this point, and mining was being carried on by hydraulicking underground, near the houses, at the time of my visit in 1895.

rubble, with some granite, plainly of later origin (morainal material). Mr. Snow supposes this channel to extend under the lava of Table Mountain, and this is not unlikely, for the bed rock is granite, and there is no hornblende schist, slate, etc., from which the pebbles of these rocks could have been derived nearer than 2 miles. The same pebbles of iron ore noted at the Reese & Jones mine occur here.

There is a small body of Neocene river gravel about 1½ miles northeast of Oregon City, on the ridge west of the North Fork of the Feather. It occupies a flat on the slope toward the North Fork. The pebbles, some 6 to 8 inches in diameter, are smooth and well rounded. The greatest thickness of the deposit is about 12 feet, but as it has been extensively mined, portions of the area may have had a greater thickness. There is no lava associated with this deposit.

As may be seen by examining the geologic map, there are many small exposures of old river gravels in the Bidwell Bar area not mentioned in these notes.

The gravels that have been grouped together as belonging to an intermediate period represent some material that Mr. Browne would perhaps put in his first period. Some of the deposits were doubtless made by rivers which occupied the same channel for a long space of time. Thus at Sweet Oil diggings the white quartz gravels may belong to the oldest gravels, and the darker gravels to a much later period. It is obvious that much remains to be done before the course of any of the Neocene rivers of the area can be indicated, except that represented by the Brandy City deposits.

THE NEOCENE GRAVELS OF BROWNE'S SECOND PERIOD.

The writer understands that the second period of Mr. Browne includes those gravels or volcanic conglomerates composed chiefly of Tertiary volcanic pebbles. Such material is rarely sufficiently auriferous to pay to mine, and although there are deposits of this nature in the Bidwell Bar area no definite notes were made regarding them. In such material there are rarely any fine layers in which we may hope to find fossil leaves. There is often, however, silicified wood embedded in the andesitic conglomerate and in the andesitic breccia that usually overlies it.

THE TERTIARY VOLCANIC ROCKS.

The Tertiary volcanic rocks occurring in the district may be grouped under the following heads:

- Basalt—
  - Older basalt (with little olivine).
  - Coarse-grained basalt or dolerite.
  - Late basalt, dark and fine-grained: chiefly dikes.
- Andesite—
  - Hornblende-pyroxene-andesite tuff or breccia.
  - Fine-grained massive hypersthene andesite.

BASALT.

There are two well-marked types of basalt in the area, one a fine-grained dark rock, like that of the Oroville Table Mountain, which has been called the older basalt, and a coarser variety, usually showing with a hand lens numerous olivine crystals.

The older basalt covers Walker Plain, the ridges north and south of the South Fork of the Feather, a considerable area on the ridge north of Fall River, and smaller areas at other points, one of which caps Kanaka Peak. Although it has been clearly shown that the older basalt is at many points covered with fragmental andesite and therefore older, there is evidence in andesite pebbles found under the flows of the basalt that some andesitic eruptions antedate the basalt. There is a series of benches of the older basalt on the south slope of the ridge north of the South Fork of the Feather, a little west of Little Grass Valley. These benches present the appearance of successive flows. The entire thickness of the basalt is there not less than 500 feet.

There is a small mass of columnar basalt on the southwest spur of Big Bend Mountain, just one-half mile west of Island Bar. According Dr. Peter Fireman, this contains 2.25 per cent of potassa and 3.62 per cent of soda.

The coarse-grained olivinitic basalt is found in smaller areas. It forms part of the level top of Mount Ararat (No. 54 Plumas), where it rests on andesitic breccia, and is much finer grained than usual. There is a considerable flow (No. 81 Plumas) north of Fall River, of which Cammel Peak is the culminating point. The basalt of the plateau in the northwest corner of the district is of the coarse olivinitic type, much of it having a marked porphyritic development. The flow may be older than the somewhat similar rocks of the Mount Ararat and Cammel Peak areas. This basalt forms the bed of the upper part of Rock Creek at one point where the elevation, according to the topographic map, is 6,200 feet, the older pre-Cretaceous rocks (here chiefly granite) rising to a greater elevation both north and south, indicating that the basalt flowed over a very uneven surface, or that it came out in a fissure at this point, or that there have been some displacements of the old Neocene surface. The problem was an interesting one, but a snow-storm coming on, no attempt was made to solve it.

The late (?) fine-grained dark basalt grouped under the third head is represented by two little buttes of columnar lava southeast of China Gulch, on the ridge west of Mount Ararat. The lava appears to have issued at these points; while it is regarded as later than the older basalt before described, no positive evidence has been obtained on this point in this region.

About 1¼ miles due west of Franklin Hill is a small basin formed in the older rocks. The rim is cut through on the north side, where the drainage of the basin escapes. An examination of the bottom of this basin shows that it is underlain by a stratified tuff, some of which dips south and southwest at angles varying from 30° to 70°. An examination of the specimens collected (Nos. 664–665 S. N.) shows that the tuff contains abundant olivine and is of a basaltic nature. Moreover, a massive dark olivine basalt (No. 667 S. N.) occurs on the west slope of the basin, and is presumed to have come from the same source as the material of the tuff. This basalt is darker in color and finer grained than the doleritic basalt of Cammel Peak, and presumably represents a distinct eruption from a different subterranean reservoir. It differs from the fine-grained basalt of the little buttes above noted in having a resinous look, such as is seen in some augite-andesites.

Fragments of serpentine, which forms the walls of the basin, are plentiful in the tuff. It is probable that we have here an old volcanic vent.

Analysis of olivine basalt (667 S. N.).

[Analyst, Steiger.]

	Per cent.
Silica	51.21
Lime	10.36
Magnesia	7.12
Potassa	.91
Soda	2.49

ANDESITE.

By far the larger part of the andesitic material of the Bidwell Bar area occurs in a fragmental or pyroclastic form, and may be called andesitic tuff, breccia, conglomerate, or agglomerate, according to the shape and size of the components. As in other portions of the Sierra Nevada, foreign material occurs, mixed with that of volcanic origin. This fragmental andesite attains a thickness of more than 700 feet on the plateau east of the head of Bear Creek, and about the same thickness on the northeast part of the Mooreville Ridge, where it distinctly overlies the older basalt.

About 1¼ miles south of Cammel Peak, in the canyon of Fall River, is a dike-like mass of fragmental andesite. The stream has cut into this dike of andesite-breccia to the depth of about 500 feet, and in the dike material in the bed of the river are embedded numerous fragments of fossil wood, as well as pebbles of pre-Cretaceous rocks and pebbles and fragments of hornblende-andesite and of the older basalt. The pieces of wood must have been washed into this fissure from the surface, together with the andesitic material in which they are embedded. The specimens of wood collected were referred to Prof. F. H.

SLATY ANDESITE OF FRANKLIN HILL.

Knowlton, who reports that "it is a Sequoia of the redwood, or *S. sempervirens*, type. The wood is not well enough preserved to enable me to say that it is the same as the living redwood, although it is undoubtedly near it." This dike-like mass is about 1,500 feet in width where crossed by Fall River. The wall rock is granite. As usual, however, the writer was not the first to note this occurrence. The place was visited by Professor Pettee[1] in 1879, but he made no investigations as to the nature of the dike.

The fine-grained hypersthene-andesite noted in two previous publications[2] is found in the Bidwell Bar area, so far as known, only at Franklin Hill and at one other point. At Franklin Hill it forms a cap having a maximum thickness of 300 or more feet on the north slope. The characteristic slaty structure of this lava is well brought out at this place, and a photograph was taken to show the feature, which is reproduced in Pl. XXI. The second locality is the little butte six-tenths of a mile south of west from the highest point of Mount Ararat.

The following are analyses of the fine-grained hypersthene-andesite of Franklin Hill. The partial analysis A is by Dr. H. N. Stokes. The analysis B is taken from a complete analysis by Dr. Hillebrand, which will be found in the table of analyses of the diorite family.

Analyses of hypersthene-andesite from Franklin Hill (661 S. N.).

	A.	B.
	Per cent.	*Per cent.*
Silica	56.99	56.88
Lime	7.83	7.53
Potassa	1.37	1.42
Soda	3.24	3.29

It will be noted that the two analyses are very nearly identical, and that the rock approaches an acid basalt in composition, but other analyses of similar andesites from the Downieville area show that the rock is usually more acid.

SUBJACENT (PRE-CRETACEOUS) SERIES.

AURIFEROUS SLATE SERIES.

Fossils of Carboniferous age have been found east of Spanish Ranch and west of Onion Valley Creek, and the clay-slates west of Island Bar appear to be the direct continuation of the Carboniferous beds near Pentz.

Limestone lenses are of rather frequent occurrence. When near granite, as at Hartman Bar, these have usually been altered to marble.

[1] Auriferous Gravels, p. 468. A notice of this dike may also be found in the Journal of Geology, Vol. III, p. 408.

[2] Fourteenth Ann. Rept. U. S. Geol. Survey, p. 489. Am. Geologist, Vol. XIII, p. 311.

Although the fossil localities are very few, the similarity of clay-slates and quartzites is so great in different parts of the area that it seems safe to regard all of them as of Paleozoic age.

THE UNALTERED INTRUSIVE IGNEOUS ROCKS.

GRANITE AND QUARTZ-DIORITE.

Nearly all of the quartz-bearing granitoid rocks of the Bidwell Bar area may be correctly called quartz-mica-diorites—that is to say, they are granitoid rocks in which the acid soda-lime feldspars (oligoclase-andesine) predominate. Usually there is both biotite and hornblende present in addition to the soda-lime feldspars, and often orthoclase, which is occasionally so abundant that the rock approaches a granite in composition. This is the case with the rock about Enterprise, on the South Fork of the Feather River. The rock southeast of Merrimac (No. 691 S. N.) may be taken as an example of typical quartz-mica-diorite. It is figured, as seen under the microscope, on Pl. XLII. In the large area of the north part of the district of which Spanish Peak is a prominent point the quartz-diorite grades over into a gabbro, which forms the upper part of the flat-topped eminence known as Bucks Mountain. This mass is intersected by a system of horizontal and vertical partings, which result in the formation of square-outlined and picturesque bluffs, and in the horizontal partings may also be found the cause of the flat top. This gabbro area is indicated on the geologic map, but as no line of demarcation between it and the surrounding quartz-diorite was drawn in the field, the area as outlined indicates in reality only a portion of the gabbro mass. An analysis of this gabbro (No. 705 S. N.) is given below with that of a quartz-diorite and a granite to show the great variation in composition of the granitoid rocks of the area.

Analyses of granite, quartz-diorite, and gabbro.

	Granite (No. 22 S. N.).	Quartz diorite (No. 691 S. N.).	Gabbro (No. 705 S. N.).
	Per cent.	*Per cent.*	*Per cent.*
Silica	70.36	59.68	50.56
Lime	3.18	6.62	14.46
Potassa	1.71	1.31	.31
Soda	4.91	3.87	2.08

The analysis of 22 is by Dr. Hillebrand, of 691 by Dr. Stokes, and of 705 by Mr. Steiger. There can be little doubt that the quartz-diorites of the Bidwell Bar areas are intrusions and therefore later than the adjoining sedimentary and igneous schists, which, near the granite contact, are often thoroughly recrystallized, at some parts having a gneissoidal appearance. The strike of the schists parallel to the contact of these granitoid rocks may also be taken as evidence that the latter are younger, as indicated in the paragraphs on schistosity and bedding. That some of the quartz-diorite is intrusive is beyond all doubt, for along the contact there are sometimes abundant fragments of the neighboring rock inclosed, forming a contact-breccia, a view of a hand specimen of which (No. 333 S. N.) is given in Pl. XXX, A. This is from the border of the quartz-diorite intrusion 4 miles northeast of Mount Hope to the south of Pinkards Creek. The inclosed fragments are a fine-grained feldspathic amphibolite, probably originally a tuff. In the bed of Mill Creek, 1½ miles northeast of Big Bar Hill, a dike of biotite-granite or quartz-mica-diorite (No. 766 S. N.) cuts the tremolite and chlorite schists, which are altered forms of pyroxenites, and are in this section associated with serpentine as part of the same rock mass. About 2½ miles south of Big Bar Hill there are streaks of serpentine, amphibolite, and quartz schists forming one series, which is cut off by a protrusion of the large Merrimac quartz-diorite area. The quartz-diorite is often intersected by systems of fissures, as in other districts. This is plainly to be seen in the amphitheater at the base of the Fall River falls, and at other points. Where it is more massive, as in the Bald Rock Canyon of the Middle Fork of the Feather River to the east of the point known as Bald Rock, there is a tendency to weather in dome-shaped forms. Near the contact with other rock masses the quartz-diorite is often schistose, as by the stage road west of the Berry Creek house, and on Spanish Peak ridge.

GRANULITE OR APLITE.

As in other districts, there are dikes of granulite and pegmatite in the granitoid rocks containing free silica, or, in other words, the quartz-mica-diorite and granite. These dikes are likewise found sometimes cutting the schists.

In the Grizzly Hill serpentine area are numerous dikes of a white rock varying in texture from coarse to fine. Some of the coarse-grained specimens may be seen with the unaided eye to be made up of quartz, feldspar, and muscovite. The microscope shows the finer-grained varieties to have the same composition. These dikes do not, as a rule, continue far, but one of them (No. 725 S. N.), one-half mile south of the summit of Grizzly Hill, was followed for about 600 feet. The maximum thickness of this dike was perhaps 15 feet. Its course was N. 60° W.

The microscope shows this rock to be composed of micropegmatite with a tendency to spherulitic forms (granophyre of Rosenbusch), muscovite in parts grouped in rosettes, and a few porphyritic quartzes. A chemical analysis indicates that the feldspar of the micropegmatite is largely albite, for the potassa is probably chiefly in the muscovite, and there is practically no lime present.

Analyses of granulites.

[Analyst, Stokes.]

	725 S. N.	565 S. N.
	Per cent.	*Per cent.*
Silica	76.00	72.65
Lime	.19	1.94
Potassa	2.77	1.61
Soda	3.52	4.92

Granulite dikes were also noted in other serpentine areas. No. 745 S. N., from the Big Bar Hill ridge, contains some microcline in addition to the muscovite, quartz, and plagioclase. The structure of this rock is thoroughly granular, and there is no micropegmatite present, or any porphyritic quartzes, as in No. 725, and this is likewise true of No. 726, which is from near 725 on Grizzly Hill. While dike 725 has a tendency to a porphyritic structure which if further developed would place it with the granite-porphyries, these soda-granulites are in general in the Downieville area and elsewhere thoroughly granular.

Dike rocks similar to those described above were noted in the serpentine by the trail from Spanish Ranch to Big Bar. No. 565 S. N., of which a partial analysis is given above, is a dike in mica-schist by the North Fork of the Feather, about 600 feet downstream from the mouth of French Creek. It is composed of feldspar, quartz, and muscovite, and seems to have undergone some crushing, resulting in the breaking up of some of the components into interlocking grains. The undulous extinction of some of the grains points in the same direction. There is some chlorite present, and aggregates of minute whitish opaque grains.

GRANITE-PORPHYRY.

In the author's previous paper the term granite-porphyry was used for a granite in which were developed large porphyritic feldspars. While this use is not without precedent, the term is generally employed for a porphyritic rock with a holocrystalline groundmass of quartz and alkali feldspar. This groundmass is sometimes so coarse that the grains may be seen by the use of a hand lens, but in all cases the groundmass is fine grained as compared with the texture of granites. Granite-porphyry, while not an uncommon rock in the Sierra Nevada, is seldom in large enough masses to be noted on the geologic maps, and but few areas of it will appear on the Bidwell Bar map. No. 213 Butte, from the south edge of the granite area to the north of Quartz Hill, is a coarse granite-porphyry, the groundmass of which contains much muscovite, in addition to quartz and feldspar. The phenocrysts are of plagioclase and quartz. The exact locality is one half mile a little north of west from Wagner's.

About 1 mile east of Enterprise, on the north side of the South Fork of the Feather River, is a dike of granite-porphyry in the granitoid quartz-mica-diorite. This dike (No. 99 Butte) has a microcrystalline groundmass of granulitic structure, composed of quartz, feldspar, and muscovite, with idiomorphic phenocrysts of quartz, plagioclase, and biotite. Nos. 103–108 S. N. are from dikes of granite-porphyry (?) in the Carboniferous slates along the Middle Fork of the Feather River at and east of the mouth of Onion Valley Creek.

The largest of these dikes at the mouth of the creek (No. 103 S. N.) is shown on the map. This contains numerous anastomosing veins of white quartz, and there are grains of iron disulphide scattered through the rock. Calcite is also present. The groundmass of all these dikes is microcrystalline with minute shreds of muscovite. While no analyses have been made of the granite-porphyries of the Bidwell Bar area and the nature of the feldspar of the groundmass has not been determined, it is considered safe to refer them to the granite porphyry group from the close resemblance to such rocks in the neighboring Downieville area.

No. 693 S. N. is a white, fine and even grained rock, somewhat decomposed and friable. It was collected by the side of the Quincy road, about 1.7 miles north of the Buckeye house, at the edge of a small area of basalt like that on Walker Plain. There is a shallow excavation here, and some well-rounded pebbles. This rock strongly resembles No. 1639 S. N., from the Sonora district, which is a soda granite-porphyry. No. 693 is composed of interlocking grains of quartz and feldspar, with abundant muscovite scales. One elongated zircon was noted. When first collected the rock was thought to be a decomposed rhyolite. It might, perhaps, be correctly termed a microgranite, but appears to be identical in structure and composition with the granite-porphyries, except in lacking porphyritic crystals. It is presumably a dike, but its relation to the surrounding schists was not ascertained.

QUARTZ-PORPHYRY (APORHYOLITE-PORPHYRY).

In the greenstone schists, about $1\frac{3}{4}$ miles northeast of Miners Ranch, is a dike about a mile in length and but a few feet in diameter. The strike of the dike is to the east of north. It is west of a small stream that drains into the Middle Fork of the Feather, about one-quarter mile east of Bidwell Bar. The microscope shows this rock to be made up of a holocrystalline groundmass that appears to be largely feldspar in irregular grains and spherulitic forms, but there is present a large amount of discoloring material in minute particles. The idiomorphic phenocrysts are of quartz and plagioclase. The quartzes are much the more abundant. Many of them are corroded, and all, or nearly all, of them show aureoles or borders composed of minute grains. It is quite possible that the groundmass of this rock has undergone devitrification.

DIORITE AND DIORITE-PORPHYRY.

Cutting the quartz diorites at many points are dark-gray, fine-grained rocks showing minute needles of brown hornblende to the unaided eye. These are abundant in the Merrimac quartz-mica-diorite area, and were found along the vein of the Reynolds gold-quartz mine and along the road to Quincy. A partial analysis of one from the Spanish Peak quartz-mica-diorite area is given below. This appears to contain some original quartz. Similar dikes are found likewise in the Auriferous slate series and associated greenstones. No. 100 S. N. cuts the Carboniferous slates on the north bank of the Middle Fork of the Feather, 2½ miles upstream from the mouth of Onion Valley Creek.

No. 102 is a similar dike eight-tenths of a mile east of the last. It cuts vertically a diabase mass on the north bank of the river. Near it were other dikes of the same rock, some of them horizontal. As has been noted before, these small dikes, often only a few inches in width, and usually extending but a few feet, are among the latest of the so-called Juratrias intrusives. It is very likely, indeed, that their origin dates from early Cretaceous time.

Diorite-porphyries like those above described are sometimes called hornblende-porphyrites, but if the latter term is used at all it should be paralleled with augite-porphyrite and used for altered hornblende-andesites.

Certain peculiar diorites containing green hornblende needles are also treated of in this section. The green hornblende of one of these (No. 817) appears to be actinolite, and as that mineral is said not to be a primary constituent of eruptive rocks, a special description of it is given below. Unfortunately, it has not been practicable as yet to separate and analyze the hornblende. Diorite No. 817 forms a narrow streak about one-half mile in length in quartz-mica-diorite, which is more or less decomposed, and satisfactory evidence that the diorite was intrusive was not found. However, the chemical and mineral composition of the diorite is so different from that of the granitoid country rock that its dike nature is regarded as probable.

Actinolite-diorite (No. 817 S. N.).

Locality: Four and six-tenths miles south of Table Mountain, on the dividing ridge between Butte and Plumas counties, by the trail to North Valley.

Macroscopically, a medium-grained greenish-gray rock, with very abundant minute glistening needles.

Microscopically, a holocrystalline rock of hypidiomorphic structure. It is composed of needles of green hornblende, often twinned, which are embedded in the later feldspar and quartz. The extinction angle measured on 5 needles varies from 16° to 20°, the average being 17°. Symmetrical extinction angles measured on three twinned needles on the trace of the twinning plane (100) vary from 13° to 17°. Except secondary chlorite and a few translucent brown grains, the rock contains practically nothing but the hornblende, feldspar, and quartz, all three of which are original constituents and quite fresh. The magnesia shown in the analysis must therefore be in the hornblende, which is therefore near actinolite, for the alumina (only 12 per cent) must be largely in the feldspar, which forms about one-third of the rock. The feldspar in part shows twinning on the albite law with rather low symmetrical extinction angles on 010 in the few grains measured, suggesting oligoclase or andesine. The quartz is clear and fresh, and, like the feldspar, undoubtedly primary. It exactly resembles in appearance quartz in general. A positive uniaxial figure was obtained with one grain. The quartzes also show minute cavities containing a liquid with gas bubble. The greenish chlorite resulting from the decomposition of the hornblende is in part spherulitic and exhibits olive-gray interference colors. While most of the feldspar is fresh, some of it contains patches of alteration products, in part brightly polarizing fibers, probably talc or sericite.

A complete analysis of this diorite will be found in the chapter on rock classification. It is, strictly speaking, a quartz-diorite, but is evidently of a very different nature from ordinary quartz-diorites.

Dike rocks are particularly well exposed along the North Fork of the Feather River. They appear to differ considerably in composition. One that is somewhat similar to No. 817 cuts the magnesian schists about one-half mile downstream from Big Bar. This is made up of feldspar largely polysynthetically twinned, a good deal of micropegmatite, with green hornblende in prisms with irregular outlines, and patches of brown mica. There are numerous irregular grains and some minute prisms of titanite present. Apatite in minute, corroded, jointed prisms is abundant. The magnesian schists referred to are altered forms of rocks of the pyroxenite-peridotite family.

Analyses of diorites.

	Actinolite?-diorite (No. 817 S. N.).	Diorite-porphyry (No. 466 Plumas).
	Per cent.	*Per cent.*
Silica	54.64	59.61
Alumina	12.09	....
Lime	7.74	....
Magnesia	11.86	....
Potassa	1.01	1.31
Soda	2.35	3.58

The analysis of 817 is by Dr. Hillebrand and of 466 by Dr. Stokes.

GABBRO.

Rocks of the gabbro type—that is to say, granular rocks composed of labradorite-anorthite feldspars with pyroxene or hornblende and usually iron oxide—are not abundant in the Bidwell Bar area. The largest mass is that before noted as forming the high, square-topped eminence known as Bucks Mountain. This gabbro (No. 705 S. N.) grades over into the quartz-mica-diorite of the Spanish Peak area, the two masses not being separated on the map by a sharp line. No attempt, in fact, was made to separate them in the field.

Hornblende-gabbro (No. 705 S. N.).

Locality: Summit of Bucks Mountain.

Macroscopically, a coarse-grained, dark, granitoid rock.

Microscopically, the rock shows a coarsely granular structure. The feldspars in most instances show albite twinning, giving in five cases symmetrical extinction angles on 010 of from 4° to 27°, showing that some of the feldspar is quite basic, in part labradorite. They occur in irregular anhedrons. The hornblende is strongly pleochroic in dark-brown and green colors, and showed an extinction angle of 29° in three cases. The hornblendes contain in a micropoikilitic manner numerous grains of hypersthene and fragments of plagioclase. Hypersthene is abundant and strongly pleochroic. It occurs to some extent in irregular, somewhat elongated, prisms, but chiefly in minute rounded grains, so that portions of the section show well the granulitic structure described by Judd in gabbros. Iron oxide is present.

On the ridge east of Cherokee Creek, in the southeast corner of the district, is a small area of gabbro. A brief description of this rock is appended:

Diallage-gabbro (No. 287 S. N.).

Locality: Eight-tenths of a mile east of Brandy City.

Macroscopically, a rather coarse-grained grayish-green rock.

Microscopically, it is composed of allotriomorphic diallage and plagioclase grains, forming a typical granular or gabbro structure. The feldspars are largely twinned on the albite law. Seven of the feldspars, cut nearly normal to the twinning plane (010), gave symmetrical extinction angles varying from 6° to 38°, showing anorthite to be present. Two crystals, twinned on both the albite and Carlsbad laws, proved to be andesine, and a third basic labradorite. The diallage occurs in well-rounded grains, as if corroded. Four of these gave extinction angles on the trace of the diallage cleavage of from 39° to 40°. The diallage is plainly altering to nearly colorless hornblende.

Near the main road, a little west of Forbestown, is a mass of coarse-grained gray-green rock (No. 341 S. N.), which the microscope shows to be a gabbro with very fresh feldspars twinned on the albite, pericline, and Carlsbad laws. The feldspars range from andesine to anorthite. The metasilicate is green hornblende, all of which may be secondary. It occurs in wedge-shaped masses between the feldspars. Iron oxide and apatite are present.

A rock of the gabbro type (No. 548 S. N.), in which the original constituents are nearly all gone, occurs in the serpentine 1.1 miles northwest of the dam of the Big Bend tunnel. Remnants of the original monoclinic pyroxene are still determinable.

THE ALTERED IGNEOUS ROCKS.

MAGNESIAN SERIES.

Serpentine, talc, chlorite, colorless amphibole, and actinolite schists are in this district associated in an intimate manner, and appear to be merely different alteration products of the same original rock mass. They are therefore grouped together under the head of Magnesian Series, since magnesia is a prominent constituent of all of them. At a number of points specimens collected show on microscopic examination that the original was a basic granular rock, varying from a pyroxenite to a peridotite. In most cases the original pyroxene and olivine are entirely gone, but some of the following specimens show these primary constituents in various stages of alteration:

Peridotite (No. 110 S. N.).

Locality: One and one-half miles west of Spanish Ranch post-office.

Macroscopically, this is an apparently fine-grained purplish and green rock, evidently in part serpentine.

Microscopically, the structure is coarse granular, and the rock is largely olivine, in rather large anhedrons, intersected by a network of cracks, which cross at all angles, and along these cracks serpentine is forming. Fibrous serpentine and tremolite occur between the olivines, evidently as alteration products. Associated chiefly with the serpentine are black streaks of magnetite in aggregates of minute grains. Chromite or picotite may be present, but was not observed.

Peridotite (No. 325 S. N.).

Locality: One-half mile north of the Winthrop House, on the road to Laporte.

Macroscopically, it is a medium-grained, dark, greenish-gray rock, showing a pearly reflection at numerous points.

Microscopically, the structure is granular, with ragged grains of nearly colorless hornblende, patches of serpentine made up of meshwork of minute fibers and remains of an olivine-like mineral. In natural light the olivine-like remains are brownish in color. One or two show traces of a parallel cleavage extinguishing parallel to the cleavage, suggesting that enstatite may be present; but most of the grains are intersected by very numerous irregular cracks and are probably olivine. Throughout the section are abundant black granules of magnetic iron, sometimes aggregated in streaks. A piece of the rock was powdered and abundant magnetic grains were extracted with a magnet. Calcite or dolomite is abundant. The chemical composition of this rock shows it to have been originally largely olivine. Although chromic acid is present, chromic iron was not observed. The chromic oxide may be in the magnetite.

Analysis of peridotite (325 S. N.).

	Per cent.
Silica	44.81
Alumina	1.88
Lime	6.58
Magnesia	30.91
Chromic oxide	.29

Peridotite or pyroxenite (No. 738 S. N.).

Locality: One and eight-tenths miles southeast of Frenchman Hill.

Macroscopically, a coarsely crystalline, even-grained, brownish-gray rock.

Microscopically, it is composed chiefly of large colorless grains, all of which are much intersected with cracks; but certain of them show still a parallel cleavage, extinguishing parallel to the cleavage. These are probably enstatite. There are colorless amphibole "calcite" and talc present as alteration products. The calcite and talc form a sort of matrix between the original grains, in which are embedded jointed fibers of colorless amphibole, sometimes grouped in radiating brushes. Some grains of iron oxide with a little iron disulphide are present in aggregates. Most of the anhedrons of the original minerals resemble olivine in their relief and irregular system of cracks, but no serpentine was noted as a decomposition product.

Serpentine (No. 116 S. N.).

Locality: One and nine-tenths miles east of Spanish Ranch.

Macroscopically, a rather thinly schistose rock, very dark green in color, with polished fracture surfaces.

Microscopically, it is composed of a yellowish serpentine, abundant black granules of magnetic iron in aggregates and grains of calcite in dolomite. The serpentine is intersected in all directions by cracks. Much of it is fibrous, polarizing in low gray tints. The magnetic iron was determined also by powdering the rock and passing a magnet through the powder.

Serpentine-amphibole rock (No. 547 S. N.).

Locality: Top of the ridge west of the North Fork of the Feather and 1.1 miles northwest of the dam of the Big Bend tunnel.

Macroscopically, a coarsely crystalline even-grained rock, apparently made up chiefly of a foliated mineral in squarish grains.

Microscopically, it is composed of serpentine and tremolite. The tremolite occurs chiefly in square ragged anhedrons or in small compact plates. The serpentine is in patches, and exhibits low gray interference tints. Intersecting this serpentine are numerous minute veins of chrysotile, polarizing in yellow tints. In natural light the ordinary serpentine shows a rather deep olive-green color, while the chrysotile is a lighter green. Extinction angles were measured on eleven hornblendes, showing maximum interference colors. These gave angles ranging from 13° to 20°, the average being 15.5°.

Chlorite-schist (No. 721 S. N.).

Locality: Four and three-tenths miles southwest of Grizzly Hill.

Macroscopically, a medium-grained, silvery, greenish rock, with abundant brown points, presumably due to the decomposition of grains of iron ore.

Microscopically, it is composed chiefly of chlorite scales, with olive-brown interference colors, the scales largely grouped radially, forming sections of spherulites which show arms of black cross.

Amphibole-schist (No. 762 S. N.).

Locality: Two miles northeast of Big Bar Hill.

Macroscopically, a dull, greenish-gray, in part reddish, fine-grained, schistose rock, with abundant minute needles.

Microscopically, it is composed of a meshwork of colorless hornblende fibers, which, in part of the sections, are more isolated and larger and embedded in a light yellow-brown chlorite, nearly isotropic in polarized light. Extinction angles measured on seven hornblendes varied from 15° to 20°, the average being 17°. This would indicate that this colorless hornblende is not typical tremolite.

Amphibole-schist (No. 769 S. N.).

Locality: Two and two-tenths miles south of east from Big Bar Hill.

Macroscopically, a fine-grained schist of a light brownish gray color, weathering reddish.

Microscopically, it is composed of rather short, stout fibers and ragged anhedrons of a sensibly colorless amphibole. Extinction angles were measured on sixteen hornblendes, those selected showing maximum interference colors. The lowest angle measured was 10° and the highest 20°, the average being 16°. Scattered through the section are minute prisms of a clear, yellow-brown mineral, with high relief, extinguishing parallel to the prism and showing no sensible dichroism. These are probably rutile. In the following analysis the TiO_2 is, doubtless, referable to the rutile, as there appears to be no ilmenite or other titanium mineral present except the rutile. The section shows that there is scarcely anything in the rock except the colorless amphibole, which, previous to obtaining the analysis, was presumed to be tremolite. The analysis may therefore be considered as representing practically the composition of this colorless aluminous hornblende.

Analysis of amphibole-schist.

[Analyst, Steiger.]

	No. 769 S. N.
	Per cent.
Silica	48.15
Titanic acid	.20
Alumina	17.66
Iron oxide	8.94
Lime	6.69
Magnesia	16.01
Phosphoric acid	.10
Water, etc	(1)
	97.75

[1] Undetermined.

Talc-amphibole-schist (No. 765 S. N.).

Locality: Bed of Mill Creek, 1½ miles north of Big Bar Hill.

Macroscopically, a dull, dark bluish-green, fine-grained rock, with slightly greasy feel.

Microscopically, it is composed of needles of colorless amphibole, in part grouped in radiating sheaves. The isolated amphibole needles, which show in cross section acute rhombohedral outlines, and large grains of deep-green, nearly isotropic chlorite, are imbedded in a matrix of minute scales with vivid colors, presumably talc, and minute scales with gray polarizing colors, presumably a chloritic or serpentinoid mineral.

Talc-amphibole-schist (No. 800 S. N.).

Locality: On the west bank of the North Fork of the Feather, about one-half mile down stream from Big Bar.

Macroscopically, a light, greenish-gray, medium-grained schist, apparently largely made up of minute needles. The rock has a distinctly greasy feel.

Microscopically, it is composed chiefly of talc in minute scales, through which as a groundmass are scattered jointed needles and sheaves with diverging fibers of a light-greenish amphibole. Extinction angles were measured on four hornblendes, varying from 18° to 22°, the average being 20°. The hornblende is, therefore, probably not actinolite, but an aluminous variety. Chromite is rather abundant, but occurs chiefly in little patches.

Talc-schist (No. 802 S. N.).

Locality: Within a few feet from No. 800.

Macroscopically, a light-greenish, very fine grained, thinly schistose rock, with rather glossy surfaces and very greasy feel.

Microscopically, it is composed chiefly of minute scales of talc, elongated, following the cleavage and arranged approximately parallel. There are present a few fibers of colorless hornblende.

Actinolite(?)-schist (No. 799 S. N.).

Locality: Within a few feet of No. 800. This schist occurs in layers, frequently dike-like, but continuing only a few feet. One layer was noted curving about a body of talc schist like No. 800.

Macroscopically, a dull-green, fine-grained schist, with abundant minute greenish needles.

Microscopically, it is composed chiefly of jointed needles and of short, irregular anhedrons of a light-greenish hornblende embedded in a fine meshwork of slightly greenish, fibrous material, which is in part hornblende and in part a chloritic or serpentinoid substance with low gray interference colors, extinguishing parallel to the fibration. Extinction angles were measured on ten hornblende needles, those selected showing maximum interference tints, the lowest angle read being 12°, the highest 19°, and the average 16°, this agreeing fairly well with actinolite.

HORNBLENDE SERIES.

Under this head are grouped a variety of metamorphic rocks: some of these are massive amphibolites and amphibolite-schists, others are greenstone-schists containing much uralite, epidote, and often chlorite, and still others are diorites, in which the hornblende is supposed in most cases to be secondary. All of the above rocks are presumed to have been derived from massive igneous rocks and tuffs. The massive amphibolites are known in some cases to have been originally pyroxenites (see No. 719); the greenstone schists containing epidote and uralite can often be shown to be altered augitic tuffs; the dioritic rocks apparently represent in some cases massive lavas, as on the Forbestown ridge, but their origin is not clear, and they are called in general metadiorites, that is to say, diorites derived from the alteration of other rocks without reference to the character of the original rocks.

Certain massive diorites represented by No. 649 may be original diorites. Rocks of this type form a large area in the Slate Creek drainage east and southeast of the Buckeye House. When the hornblende in diorites is uralitic they may be called uralite-diorites, but such rocks are included in the broader term metadiorite. An example of this is No. 534 S. N., from the Forbestown ridge, an analysis of which has been made.

There are small amounts of chlorite, tremolite, and talc schists, usually occurring in narrow streaks. In general, however, the characteristic mineral is green hornblende, differing from the hornblende (colorless hornblende and actinolite) of the magnesian series in usually containing much alumina,[1] so that the rocks grouped together under

[1] As may be noted in the description of No. 769 S. N., in the paragraphs on the magnesian series some of the colorless amphibole contains much alumina, but it is regarded as probable that the distinction here made may hold in most cases, although it is obvious that more analyses are needed to determine the point.

the head of hornblende series might better be called the aluminous hornblende series. Those metadiorites and greenstone-schists (see Nos. 552 and 115) which have been metamorphosed by dynamometamorphic and hydrometamorphic agencies usually present a confused appearance under the microscope, due to the great abundance of epidote, uralite, calcite, chlorite, and other secondary minerals in minute particles. When the original feldspar remains it is usually turbid. When the same rocks have been further altered by contact metamorphism this confused appearance disappears and all of the elements become thoroughly recrystallized. The feldspar and quartz occur largely in clear grains, often forming a typical mosaic structure; the hornblende assumes idiomorphic outlines and is no longer in minute fibers; epidote, chlorite, and calcite usually disappear altogether, and the iron occurs as magnetite and ilmenite. Such hornblende-schists are very abundant in the Bidwell Bar area. Nos. 796 and 746 are good examples. In the same way the more massive uralite-diorites are recrystallized into metadiorites in which all the constituents are fresh. A good example of this is No. 518 S. N. This is practically a contact-metamorphic form of uralite-diorite No. 534, both being from the same area.

Some of the massive amphibolites (see No. 318 S. N.) containing little feldspar are metamorphosed by pyroxenites. Included in the hornblende series are some layers of lighter-colored altered lavas which contain little hornblende or metasilicates of any kind. An example of this is No. 568 S. N., from the North Fork of the Feather River, south of Big Bend Mountain. This appears to have been an altered acid andesite. Another example is No. 903 S. N., from Big Bend Mountain. They are very similar macroscopically and microscopically to No. 25 S. N., an altered andesite or porphyrite from Eldorado County, and it is likely that they are similar in chemical composition. An analysis of No. 25 is given in the table of analyses of the diorite family. The silica percentage of No. 25 (68.58) is that of a dacite, and there is reason to believe that free silica must exist in the groundmass of these acid andesites, although none has been identified, and there are no quartz phenocrysts in the sections examined.

No. 329 may be regarded as an altered massive lava, probably an augitic lava, in which the metasilicates were present in considerable amount, but are now entirely gone and are replaced by uralite and epidote. The apparently acid character of the feldspars would place this rock with the andesites, but the great alteration and obscured structure, taken together with its basic composition as seen in the analyses, make this doubtful.

Following Dr. Florence Bascom,[1] such altered or devitrified andesites as Nos. 568 and 903 may be called apo-andesites. In the Rosenbusch and Fouqué and Lévy systems they would be called porphyrites.

[1] Bull. U. S. Geol. Survey No. 136, 1896, p. 38.

The following are analyses of metadiorites and greenstone-schists from the Bidwell Bar area:

Analyses of metadiorites and greenstone-schists from the Bidwell Bar area.

	Uralite-diorite (No. 534 S. N.).	Altered lava (?), greenstone (No. 329 S. N.).	Chloritic schist (No. 335 S. N.).
	Per cent.	*Per cent.*	*Per cent.*
Silica	51.07	49.86	41.61
Iron oxide	12.42	14.29	19.76
Lime	7.89	7.12	5.92
Magnesia	4.84	4.35	7.26
Potassa	.16	....	....
Soda	5.01	....	....

No. 534 is from a complete analysis by Dr. Stokes, and Nos. 329 and 335 are partial analyses by Mr. George Steiger.

The following description of some of the rocks included in the hornblende series represent fairly well the different types, these being selected from about 100 thin sections:

Uralite-diorite (No. 534 S. N.).

Locality: One mile southeast of Forbestown, by the main stage road.

Macroscopically, a medium and even-grained, dark-green, granular rock, weathering a reddish color.

Microscopically, the structure is diabase-granular. The rock is composed of divergent lath-like plagioclases, between which green hornblende occurs in more or less wedge-shaped grains. Iron oxide is abundant. It is apparently magnetite, and occurs in squarish grains. The plagioclase laths are often twinned once only, on the albite law, but occasionally on both the albite and the Carlsbad laws. Eleven laths gave symmetrical extinction angles on the trace of 010 of from 3.5° to 15°, the average being 8°. One feldspar twinned both albite and Carlsbad proved to be andesine, and another labradorite. It is probable, therefore, that most of the feldspars belong to the oligoclase-andesine series, and the rock is therefore a diorite. This is rather remarkable, considering the basic character of the rock as shown by the chemical analysis. However, if we suppose the magnesia (4.84 per cent) to have gone entirely into the hornblende, which is evidently an aluminous variety, and the hornblende to contain nearly as much lime as magnesia, which is usually the case, then about 4 per cent of the lime will be in the hornblende, leaving about 4 per cent for the feldspars. Supposing the soda to be chiefly in the feldspar, we should then have 4 per cent of lime and 5 per cent of soda for the feldspar, a reasonable estimate. In this case the feldspar would be chiefly andesine. The rock may be called, therefore, a basic diorite.

In two other metadiorites similar to No. 534 the feldspars appear likewise to belong to the oligoclase-andesine series. One of these (No. 522 S. N.), from southwest of Woodville, gave symmetrical extinction angles on the trace of 010 of from 10.5° to 15° in seven cases, the average being 12.5°. The other (No. 536) from 1½ miles southwest of Stringtown Hill, gave symmetrical extinction angles on the trace of

010 varying from 5° to 14°, the average being 8°. These three rocks, together with No. 518, represent very well the fine, even-grained greenstones of the Forbestown ridge.

Contact metamorphic hornblende-diorite (No. 518 S. N.).

Locality: By new lower road to Forbestown, 1.7 miles east of south from Sunset Hill, and about one half mile from the contact with the Swedes Flat quartz-diorite area of the Smartsville district.

Macroscopically, a fine, even-grained, dark iron-gray rock weathering greenish. Except in being finer grained, the texture is very similar to that of No. 534, which is part of the same rock mass, and it may be considered a contact-metamorphic form of No. 534.

Microscopically, it is similar in structure to No. 534, the chief characteristic being the elongation of the divergent feldspars parallel to the edge *pg'* (001) (010), as in diabases, the intervening spaces between the feldspars being filled chiefly with a mosaic of minute feldspar and a few quartz grains (this mosaic is wanting in the uralite-diorite 534), with compact green hornblende in grains and short prisms. The edges of the feldspar laths have an irregular corroded outline, which is not the case with 534. Metallic iron oxide is abundant in small grains. Some of the rock was powdered, and the iron oxide was found to be strongly magnetic. It is therefore presumed to be magnetite. Epidote occurs at one point only. In general all the minerals in the rock are fresh; the lath-shaped original feldspars only being somewhat turbid. It may be regarded as a uralite-diorite like No. 534, or like No. 536, which has undergone recrystallization as the effect of the heat of the intrusive granitoid rock. No. 536 contains uralite, iron disulphide, and clouds of gray grains, white by reflected light. All these constituents have disappeared in the recrystallized rock. The green compact hornblende of these recrystallized greenstones has been well represented by Mr. W. Lindgren in his paper in the Fourteenth Annual Report of the Geological Survey, Pl. XVIII.

Hornblende-gabbro or diorite (No. 795 S. N.).

Locality: One and a half miles west of the Campbell Lakes. There is along the fortieth parallel and to the north of it a very considerable amount of coarse dioritic rock like 785.

Macroscopically, a dark greenish-gray, coarsely crystalline, massive igneous rock, apparently made up only of hornblende and feldspar.

Microscopically, a coarsely granular or typically gabbro structure composed of nearly even grains of compact green hornblende (one noted twinned), the intervening spaces being filled with saussurite, formed by the decomposition of the feldspars.

Quartz-bearing hornblende-diorite (No. 649 S. N.).

Locality: Two miles southeast of the Buckeye house, in the Slate Creek drainage.

Macroscopically, a dark-greenish schistose dioritic-looking rock of medium grain.

Microscopically, the structure is granular. The plagioclase occurs in squarish or rounded grains, some of them twinned with broad lamellæ. The green hornblende is in rather narrow prisms, some of which show twinning. In cross section the characteristic cleavages are seen to be well developed. The hornblende appears to be original. The feldspars are turbid and filled with minute grains of epidote or zoisite. Quartz occurs sparingly in grains which have been largely broken into smaller grains. At many points between the feldspars are aggregations of minute grains. The rock has evidently undergone crushing, as shown by the broken-up quartzes and fractured feldspars.

Massive amphibolite (No. 318 S. N.).

Locality: Nearly 2 miles northeast of the Buckeye house, a little southeast of the Slate Creek bridge. Most of the greenstone about this mass is much finer grained.

Macroscopically, a very coarsely granular rock of a light grayish-green color, apparently made up entirely of anhedrons of a foliated mineral, either hornblende or pyroxene.

Microscopically, the structure is coarsely granular. Grains of compact green to brown hornblende occur, showing the characteristic cleavage and altering to uralite.

Pyroxenite (No. 719 S. N.).

Locality: About 1.7 miles a little east of south from Grizzly Hill. A small amount of this rock in an area of the hornblende series.

Macroscopically, a green, coarsely crystalline rock, apparently all pyroxene.

Microscopically, a coarsely granular rock made up chiefly of monoclinic pyroxene, which is in spots altering to a slightly greenish hornblende and to epidote, the latter in large grains.

Contact-metamorphic amphibolite-schist (No. 796 S. N.).

Locality: About two-tenths of a mile upstream from Big Bar on the west side of the North Fork of the Feather. This rock is from near the granite, and shows the effect of contact metamorphism in its complete recrystallization.

Macroscopically, a dark, fine-grained schist, apparently containing minute mica foils. It is cut by a minute white vein.

Microscopically, it is composed of minute, interlocking, clear, gray grains, probably of both quartz and feldspar, most of which show no twinning or cleavage, and minute rounded grains and irregular prisms of a compact green hornblende, with a minor amount of a greenish-brown mica forming a streak at one point. The rock is schistose, as shown by the hornblende prisms and biotite foils being roughly parallel. A minute vein with relatively large quartz grains and a few feldspars showing albite twinning cuts the section. The relief of the quartz and feldspar is very nearly the same, and the quartzes show a set of parallel fractures which are parallel to the direction of schistosity. A positive uniaxial cross was obtained with one of the quartzes.

Contact-metamorphic hornblendic schist (No. 719 S. N.).

Locality: Summit of Bear Ranch Hill.

Macroscopically, a hard, schistose, fine-grained, dark slate-gray rock.

Microscopically, the rock is composed chiefly of clear, minute, gray grains, forming a mosaic structure. These grains are probably both feldspar and quartz, judging from analogy with similar coarser-grained schists. Some of the clearest grains seem certainly quartz. Green hornblende occurs in minute slender fibers. This appears to be the same recrystallized hornblende as was found in No. 518, and to differ merely in the form of occurrence. Iron oxide is more sparingly present than in 518. It is probably magnetite. A green-brown mica in minute foils is less abundant than the hornblende. The original character of this rock is uncertain. It may easily have been a fine-grained tuff of intermediate composition.

Uralite schist (No. 552 S. N.).

Locality: By an old ditch west of the North Fork of the Feather River, 1.4 miles southwest of Big Bar Hill.

Macroscopically, a thinly schistose green rock.

Microscopically, the chief constituent is a nearly colorless uralite in very minute fibers and in ragged prisms. Finely fibrous chlorite with low gray interference colors occurs in spots, and epidote in minute grains, which show best without the analyzer. The rock is regarded as the result of dynamometamorphism, and does not show any effects of contact metamorphism. The nearest granite mass, that of Concow Valley, is 1½ miles away.

Apo-andesite or porphyrite (No. 903 S. N.).

Locality: Big Bend Mountain, nine-tenths of a mile northeast of Big Bend camp.

Macroscopically, a hard, fine-grained, greenish rock, apparently an altered andesite.

Microscopically, the rock is porphyritic, with a fine-grained microlitic groundmass in which are phenocrysts of plagioclase. The feldspar microlites of the groundmass exhibit in many cases a nearly parallel extinction and are probably oligoclase. The phenocrysts appear to be somewhat more basic. Clouded aggregates that obscure the section are in part epidote. The section is cut by veinlets of quartz.

Apo-andesite (porphyrite) schist (No. 329 S. N.).

Locality: About 1.3 miles a little west of south from Strawberry Valley, in a ravine draining into Owl Gulch. There are some narrow streaks of tremolite-schist in the 329 area in the same ravine. Note the partial analysis given above.

Macroscopically, a dark bluish-green, fine-grained schist. Grains of iron disulphide are to be noted.

Microscopically, the structure is microlitic. The lath-like plagioclase may be the only original constituent remaining. These chiefly extinguish nearly parallel to their length and are presumed to be oligoclase-andesine, but may be more basic. They are largely twinned, but the trace of the twinning plane is not sharp, and the microlites are in all cases turbid. As seen in natural light, these feldspars appear to be embedded in a green material, which is seen with crossed nicols to be chiefly aggregates of uralite fibers with more or less epidote in grains. Iron oxide of a dull-black color in aggregates is rather abundant. Minute cavities are filled in some cases with interlocking quartz grains; sometimes with calcareous carbonate and epidote. Little veinlets cutting the section are made up of a quartz feldspar mosaic with some greenish-brown mica, and at other points of quartz and epidote and calcite. There are a few scattered grains of pyrite or marcasite.

Chloritic schist (No. 335 S. N.).

Locality: By the Forbestown ditch, 3 miles west of Strawberry Valley.

Macroscopically, a fine-grained, dark bluish-green, schistose rock with irregular fracture.

Microscopically, it is composed chiefly of green chlorite in minute patches and scales, iron oxide in very minute grains, and calcite, with a large amount of feldspathic material which is much obscured by the other constituents. The chlorite is nearly isotropic in polarized light. The rock has a schistose structure, due to the arrangement of the grains of iron oxide more or less roughly in layers, which are often contorted. In natural light the schistosity is best shown by the parallel layers of iron-oxide grains. Uralite is present in small amount, in minute fibers. A partial analysis of this rock shows the composition to be quite basic. It is associated with other dark, fine-grained greenstones, like No. 329.

Apo-andesite (porphyrite) (No. 568 S. N.).

Locality: By the Big Bend trail on the north side of the Feather River, opposite Berry Creek Bar.

Macroscopically, a grayish-green, fine-grained, somewhat slaty, flinty-looking rock. Looks like a pre-Tertiary andesite. Some grains of iron disulphide.

Microscopically, it is a porphyritic rock with a finely microcrystalline, granular groundmass, containing chlorite scales in abundance, which are arranged in layers suggesting traces of an original flow structure. The groundmass is presumed to have undergone devitrification—that is, to have been originally glassy. The plagioclase phenocrysts are beautifully fresh, many of them with interrupted borders of chlorite. They are twinned on the albite law in broad lamellæ. Symmetrical extinctions on the trace of 010 in two cases gave 11° and 17°. In some of the phenocrysts there are grains of epidote and minute flecks of chlorite. There is iron oxide in small grains scattered through the section, and epidote.

Epidote-schist (No. 115 S. N.).

Locality: Near Rock Creek, 1.7 miles south of east from Spanish Ranch post-office.

Macroscopically, a fine-grained, light-green, schistose rock.

Microscopically, the rock is composed chiefly of minute grains of epidote, with minor amounts of quartz and feldspar in minute grains, and scattered uralite fibers, the whole presenting a schistose appearance, due to the grouping of the epidote grains in layers and to the parallel arrangement of the uralite fibers. The latter are abundant at one point in the section. A small part of the section shows a distinct cataclastic structure, being made up of broken and faulted twinned plagioclase feldspars cemented by calcite, with a minor amount of secondary hornblende in rather large fibers, some of which are sensibly bluish. The rock is presumed to be a crushed and altered tuff. Except the twinned feldspars, probably none of the original grains of the rock remain.

ECONOMIC GEOLOGY.

GOLD GRAVELS.

The gold-bearing gravels formed by a preexisting system of rivers of Tertiary age have been treated of under the head of Neocene river gravels. At a number of points morainal material or accumulations of loose rock due to ice action have been found to be auriferous. These localities are noted under the head of Evidences of glacial action. The auriferous gravels of the Pleistocene lake that formerly filled Meadow Valley are noted in the description of that deposit. No detailed description seems necessary of the Pleistocene gravels, which are found along nearly all the streams forming the so-called "bars."

Among the notable efforts to mine the river beds themselves is that which proved unremunerative at Big Bend. A tunnel was constructed at a point on the North Fork of the Feather where the river turns sharply to the east. The river then flows south for some distance, and then bends again to the west, making a magnificent horseshoe bend, having a length, following the course of the river, of perhaps 12 miles. The tunnel is about 2 miles in length and opens into the head of a ravine on the west of Big Bend Mountain, known as Dark Canyon. A dam was built at the northeast end of the tunnel, by which, at low water, the river was diverted into the tunnel. The amount of gold obtained from the river is not known to the writer. The abundance of large bowlders in the bed of the stream, and consequently the expense of getting out the gold, is said to have been one reason why the undertaking failed to be profitable.

An extremely pretty example of a horseshoe bend on a diminutive scale may be seen on the Little North Fork of the Middle Fork of the Feather, 3 miles southeast of Merrimac, where the river is joined by a branch creek, known as Bear Gulch. In this case, however, the horseshoe itself is not mined. There is here a narrow gorge in the granite bed-rock containing pot-holes from 5 to 20 feet in diameter. A dam built across the Little North Fork just upstream turns the water into a flume, leaving the bed of the stream exposed for mining. The gravel is sluiced into the narrow gorge of the horseshoe and allowed to accumulate there during the summer to be carried off by the winter floods. This mine is known as the Horseshoe mine.

THE GOLD-VEIN DEPOSITS.

In the Bidwell Bar area the gold-bearing veins are, as in other districts, composed chiefly of quartz, but there are some notable exceptions, namely, the auriferous barite veins of Big Bend Mountain, and the Diadem lode deposit. The richest mines are those in the neighborhood of Forbestown. For information concerning the production of these and other mines the reader is referred to the reports of the State mineralogist of California, and to the columns of the Mining and Scientific Press. The mines of the Forbestown district are chiefly in the fine-grained uralite-diorite or greenstone previously described, although the Shakespeare is close to an area of a granitic rock, and the diorite that forms the country rock of this mine is coarser than usual. Several of them are noted on the economic sheet, but the Denver mine was the only one entered. This is on the north slope of the Forbestown ridge, about 1½ miles west of Forbestown. The strike of the vein is about 25° south of west, and the dip 70° to 80° to the north. The vein matter is quartz of the kind called ribbon quartz, and the vein has a width of from 5 to 10 feet. As at Forbestown, the country rock is fine-grained uralite-diorite.

The Bee Hive mine, on the west slope of Mount Hope, near the stage road, is on the west edge of an area of coarse quartz-diorite which forms the hanging wall of the vein. The course of the vein, which is from 3 to 6 feet in thickness, is about N. 8° E., and the dip 45° E. The quartz contains free gold, some galena, and sulphide of iron. There is more or less talc or sericite mixed with the vein material, and this may cause the loss of some of the fine gold, the talc adhering to the gold particles and preventing amalgamation. To the west of the Bee Hive vein the country rock is clay-slate. It is therefore a contact vein.

The Big Bend Mountain district was visited by the writer, with Mr. W. Mullen, in 1894. A considerable part of Big Bend Mountain, as exposed along the road from the bridge over the West Branch of the North Fork of the Feather River to the abandoned village of Big Bend, is made up of clay-slates, probably Paleozoic in age, with layers of greenstone schists representing original augitic tuffs. The rocks along the east and south base of the mountain, as seen along the river (the North Fork of the Feather), are almost entirely greenstones, with one or two layers of sedimentary mica-schists. These greenstones are largely amphibolitic rocks representing original surface lavas and tuffs, probably augitic andesites, but now containing little or no augite.

There are a number of quartz veins in the schistose rocks above described that deserve prospecting.

Mullen's vein strikes north and south, and the Bohanan veins northwesterly. Near the latter veins is a dike of granitoid rock, the relation of which to the vein was not determined. By far the most interesting feature, however, was the occurrence of a vein of barite, or heavy spar, containing gold. The deposit is known as the Pinkstown ledge. It is located about half a mile due south of the highest point of Big Bend Mountain. The ledge strikes N. 13° W. and dips at a high angle (about 80°). It is from 2 to 3 feet wide where best exposed at the north end, and is composed of a soft, heavy mineral, some of which is coarsely crystalline, with a granular structure, but most of it is finer grained, with a schistose arrangement of the granules. No single crystals of the mineral were noted having a greater maximum diameter than five-eighths of an inch. Dr. Hillebrand made a chemical examination of this soft mineral, and reported it to be barite. Three sections of the barite were examined microscopically, and these show that, when fresh, there is scarcely any impurity in the mineral, and in fact no other substance was noted except scattered minute, reddish, opaque grains, which are reddish-yellow by reflected light, without metallic luster. They may be limonite. Many of the barite grains show distinct cleavages, which appear in the thin sections to intersect at nearly right angles.

A tendency to a radial structure like that of epidote was noted at several points in the section. The relief of the barite is rather high. A sample was examined for gold by Dr. Stokes, who reported that "the barite contains gold, but too small in amount to be determined in the wet way." There is said, however, to be enough gold in the deposit to pay to work, and the writer understood that the owner of the ledge obtained gold from it by grinding up the ore in a hand mortar and panning it.

The exact nature of the schist inclosing the barite vein was not determined. On the geologic map this vein is shown as being inclosed in the greenstone series, but there appeared to be a quartzite-like rock on the top of the ridge near the vein. The surrounding rocks, however, belong to the greenstone series, although, on account of their decomposed condition, the exact nature of all of them was not made out. There are, however, no definite clay-slates or mica-schists near the vein. The south extension of the Pinkstown ledge owned by Clarke was examined, but no barite was found, the rock on the dump being a white, fine-grained schist with a greasy feel. This, as seen in thin section, is composed chiefly of minute, brightly polarizing fibers, perhaps talc, with numerous minute cubes of pyrite, arranged in rows.

In the Bidwell Bar area quartz veins are very rare in the serpentine areas, and not common in the granite or quartz-diorite areas, with some exceptions to be mentioned later. They are common, however, in the talc schists, as may be seen at Quartz Hill, north of Lumkin, but the writer knows of no case where the veins in the last-named rock have warranted the erection of a stamp mill.

Near Merrimac, in the granitoid quartz-diorite, some quartz veins have been found to contain considerable gold. One of these, the Reynolds mine, was worked for some time.

GRANITE-BASIN DISTRICT.

The following notes on this district are taken from a report by Mr. J. A. Edman, of Meadow Valley, who has made a very careful study of gold ores by the aid of the microscope:

The quartz veins worked are here chiefly in granite, bounded on the east by hornblende rock and to the west by talcose schists and soapstone. The veins have a general northeast and southwest trend, standing vertical or at a high angle; they are narrow and seldom reach over 2 feet in width. The walls are generally well defined and the granite is decomposed near the surface. Quartz forms the vein matter, carrying much gold-bearing pyrites, with small quantities of galena and zinc blende; near the surface the ore is oxidized to limonite, associated with wulfenite and lead sulphate. This camp has been in existence for over twenty years as a quartz-mining region, but developments have not reached any great depth, seldom exceeding 100 feet. The ores are high-grade, and may be estimated to average $20 per ton. Two small stamp mills are in operation, depending on the free gold for their profit, as the high-grade sulphurets are generally wasted.

Quartz veins in the clay-slates are numerous in the Bidwell Bar area, as elsewhere. One of the most interesting lodes in these rocks is south of Meadow Valley, and has been worked at various times for many years by Mr. J. A. Edman, who gives the following account of it:

DIADEM LODE.

The principal mines of this lode are the Diadem, Red Point, Victor, Honeycomb, and Chicken Flat, at an altitude of 4,700 feet. The strike of the Diadem lode is nearly N. 37° W., dipping 60° to the northeast. The average width of the lode in the Diadem mine is 60 feet, and the vein matter is a highly ferruginous mass of decomposed material, consisting of quartz, talcose slates, oxides of iron and manganese, with bodies of aluminous rocks forming horses therein, and large masses of siliceous dolomite appear in the lower levels, in all stages of alteration. This mine has been exploited to a depth of 300 feet, and furnishes enormous masses of low-grade ore, with very rich veins containing coarse gold on the foot wall. One-half of the lode is estimated as available for profitable milling. Rich selenides of gold and silver, combined with lead and copper, are found as a rarity; various gold-bearing sulphurets, varying much in value, appear at all points of the workings.

The Diadem lode is thought by Mr. Edman to have been originally dolomite, which has been in part replaced by quartz and other vein material. In addition to the minerals named above, rhodonite, a silicate of manganese, and zoisite are said to occur in this lode. There is a vein of pyrolusite, or oxide of manganese, about 2 to 3 feet thick, about 150 feet vertically below Mr. Edman's house, in or near the lode. As noted under Faulting, there is evidence of recent movement along this lode.

IRON ORE.

According to Mr. Edman, there is a well-defined vein of hematite and magnetite parallel with the Diadem lode and distant 400 feet westerly, conforming to it in dip and strike. It may be traced for more than 2 miles, and runs from 6 inches to 3 feet in width. The adjoining chloritic slate is largely charged with grains of magnetic iron.

CHROMITE.

Bodies of chromic iron in place are noted on the economic sheet in the serpentine belt about 2 miles west of Spanish Ranch post-office, and about three-fourths of a mile southwest of Meadow Valley, to the south of Clear Creek.

According to Mr. Edman, pebbles of chromic iron are abundant in the Meadow Valley conglomerate.

LIMESTONE AND MARBLE.

The limestone lenses have been noted on the geologic map, from which their location can best be determined.

Certain of these masses have been converted into marble, some of which is massive and even-grained and will probably answer for ornamental and building purposes. Such a mass is Marble Cone, on the north side of the canyon of the Middle Fork of the Feather, east of the mouth of Willow Creek.

CHAPTER IV.

THE DOWNIEVILLE AREA.

Like the Bidwell Bar district, the area now to be described is as a whole well wooded, with considerable areas thickly covered with brush. Those ridges that rise above 7,000 feet are, however, much more scantily clothed with vegetation, and on some slopes where glaciers have cleaned off the loose rock, as at the Sierra Buttes and the basin of the Bear and Long lakes, the rocks are almost entirely devoid of any covering. The highest elevation is the main peak of the Sierra Buttes, in the southeast section, with an altitude of 8,615 feet, and the lowest, Indian Valley, in the southwest corner, with an elevation of about 2,400 feet. The Middle Fork of the Feather River, which crosses the central part of the district, is remarkable as being the only river that nearly cuts across the entire width of the Sierra Nevada. The main rivers have a westerly course, but this is not true of their tributaries, which flow in all directions.

In the central and southeastern part of the area are numerous lakes, largely the result of glacial action. Particularly attractive is the group of lakes on the east slope of the high ridge that joins the Sierra Buttes and Eureka Peak. Of these the Sardine lakes and Gold Lake are the most accessible, there being a wagon road to each. Nearly all of these lakes contain trout, and, with the grassy meadows near them, furnish ideal places for summer camping.

EVIDENCES OF FAULTING.

In a bulletin published in 1886,[1] Mr. Diller treats of faulting in Plumas County, and indicates three normal faults of considerable throw, resulting in three tilted blocks, the depressed or western part of each of which is now covered with Pleistocene valley deposits. The most western of these normal faults is east of Clermont Hill, American Valley lying at the base of the scarp; the second fault scarp is represented by the east slope of Houghs Mountain, at the north end of the high ridge of the Grizzly Mountains, with Indian Valley at its base; the third scarp lies west of Honey Lake. In a later publication,[2] however, Mr. Diller considers the displacements that have occurred on the east slope of the Grizzly Mountains, or about Taylorville, to have resulted from overthrust faulting, a kind of displacement that is

[1] Bull. U. S. Geol. Survey No. 33, pp. 12-16.

[2] Bull. Geol. Soc. Am., Vol. III, pp. 384-394.

said to occur usually at the time mountain ranges are folded, which in the Sierra Nevada would be about the close of the Jurassic.

The steep east slope of the Grizzly Mountains must then be explained by stream erosion since the post-Jurassic upheaval, and in that case there is no reason to resort to the supposition of normal faulting to explain the steep northeast slope of Clermont Hill and the steep slope west of Spring Garden Creek.

In a paper published in 1892 Mr. James E. Mills, who has made a very detailed study of the geology about American Valley, concludes that "the Tertiary and Quaternary uplifting, to which the relative relief of the present range is due, has been principally if not entirely by faulting." From the context it is apparent that the faults recognized by Mr. Mills in Tertiary and later time are normal faults.

In 1891 the writer published some evidence of normal faulting in Mohawk Valley.[1]

To one standing on the summit of the high wide plateau west of Mohawk Valley and looking eastward, the region to the east of the valley presents all the appearance of being a downthrown area. The slope to the west of the valley is an exceedingly steep one, rising at some points 2,500 feet in 1¾ miles. This slope, moreover, is composed wholly of the pre-Cretaceous rocks, although these are hidden at some points by morainal débris. To the east of the valley Tertiary volcanic material covers large areas and forms the summits known as Jackson Mountain, Penman Peak, and Pilot Hill. Where the pre-Cretaceous rocks occur they are at low elevations, at no point within 3 miles of the valley having a greater elevation than 5,300 feet or 800 feet above the lower part of Mohawk Valley. The best evidence that a great displacement has occurred here in Tertiary time consists of the presence of river gravels on the high plateau to the west. At one point, about 2½ miles northwest of Haskell Peak, there is a heavy mass of well-rounded gravel at the very edge of the escarpment, and a considerable portion of this mass has by gravity traveled down the slope, so that the apparent thickness of the deposit is about 500 feet. To the northeast and west of Haskell Peak, and also close to the edge of the escarpment, are smaller masses of similar gravel, all of them capped with rhyolite and all at an elevation of about 7,000 feet. It is evident that we have here remnants of an old river deposit formed by a stream flowing at a moderate grade. It is not likely that any geologist will hold that such a stream could have existed along the edge of a plateau having a steep escarpment. There can be no reasonable doubt that since these gravels were deposited a profound displacement has occurred, in virtue of which that portion of the former plateau lying to the east of the present escarpment has dropped down 2,000 or more feet and now lies in part buried beneath the sediment of the former Mohawk Lake and beneath Tertiary lavas. This downward displacement must have been preceded by an elevation of the range.

[1] Mohawk Lake Beds, Bull. Phil. Soc. Washington.

Mohawk Lake, just referred to, as will be seen later, occupied the present Mohawk Valley in Upper Miocene or Pliocene time, although the lake at this period may not have been a deep body of water. The basin occupied by this lake may be regarded as the result of the displacement above referred to, in which case the faulting probably took place in Miocene time, for the lake beds lie at nearly all points approximately horizontal, showing that the steep slope to the west must have existed when they were deposited. The writer refers here particularly to the older Tertiary beds, composed chiefly of fine white sediments. It is of course equally true that the Pleistocene lake beds which cover up and largely conceal the older beds are also approximately horizontal. These more extensive Pleistocene beds were deposited by a body of water of some depth, due to the damming back of the water by andesitic breccia as described under the head of Lake Beds. Slight displacements have, however, occurred in comparatively recent times in the lake beds, indicating a zone of weakness presumably established at an earlier date as above indicated. The lake beds are disturbed in the immediate vicinity of this line of faulting, but rest horizontally a few feet to the east and west of the fault line so far as determined.

Faults with a small throw in Pleistocene sediments were noted on the east side of the Middle Feather River, opposite Wash post-office, and on the south bank of the river, about 1 mile upstream from Wash post-office. About a mile farther east, where most of the fossil leaves were collected that are referred to under Tertiary lake beds, a fissure was formed in the tuff and breccia beds at the time of an earthquake (about 1876). This fissure is said by Abel Jackson, on whose place it is located, to have been about 2 feet wide, and he says that warm air came out of it for a time after the earthquake. The place was formerly the resort of numerous rattlesnakes, attracted no doubt by the warmth. At the time of my visit (1889) air slightly warm (as tested by the hand) and moist still issued from the holes along the former fissure. A little east of the fissure is a warm sulphur spring. Near this is another spring which soon after the earthquake was so warm (according to Mr. Jackson) that the hands could not be held in the water. As further evidence of a disturbance at this point it may be said that the shales from which the leaves were obtained dip from 5° to 30° to the west.

Farther south, just east of the springs at the Sulphur Spring House, the lake beds are likewise flexed, at one point dipping 22° to the southwest. The so-called sulphur springs had in 1890 a temperature of 75° F., as tested by an immersed thermometer.

Artesian wells along the west side of Sierra Valley are said in some cases to strike hot water, which may be regarded as evidence of the existence of a fissure. The fault said by Mr. Mills to exist along Spring Garden Creek and near Cromberg,[1] on the Middle Feather, may be correlated with the zone of faulting above indicated.

[1] Bull. Geol. Soc. Am., Vol. III, p. 418.

In conclusion it should be stated, however, that the writer's investigations of the geology about Mohawk Valley have been of a somewhat hurried nature. A more thorough study of the district would bring out many points of interest, and it is hoped that this may be undertaken by the future investigator.

For other evidences of faulting the reader is referred to the description of the Neocene river gravels.

THE SUPERJACENT PLEISTOCENE AND TERTIARY SEDIMENTARY TERRANES.

PLEISTOCENE ALLUVIAL DEPOSITS.

The most recent Pleistocene deposits, forming the alluvial bottom lands, occur along streams and form the lowest portions of most of the valleys. On the geologic map these most recent deposits have not been separated from the earlier Pleistocene. American Valley appears to represent a basin formed in part by orographic causes at the time the normal faulting to the west of Spring Garden Creek and northeast of Clermont Hill may be supposed to have occurred.

Grizzly Valley is nearly surrounded by volcanic ridges, and may perhaps represent an inclosure formed by the piling up of the volcanic material about it. The clay and fine sediment filling it are chiefly of early Pleistocene age, with bottom lands along Grizzly Creek and its branches, of later formation.

The deposits along the Feather River from Bell's Bar up to the mouth of Jackass Creek are chiefly coarse gravels, and materials of the same sort underlie Long Valley. The age of these is presumed to be chiefly early Pleistocene. These gravels have been mined at Bell's Bar, along Rattlesnake Creek, and at other places. On the west of Willow Creek, about one mile north of Nelson Point, is a considerable area of early Pleistocene gravel. The western border of this area has an elevation perhaps 400 feet greater than the portion of the area bordering on Willow Creek.

Along most of the rivers are to be found the usual bars, of which English Bar, on the Middle Fork of the Feather, is a good example. All along the North Fork of the Yuba River, from Indian Valley to Sierra City, are gravel banks or bars, some of them as much as 150 feet above the present river. There are pebbles of Tertiary volcanic rocks mixed with those of older rocks in these gravels. Downieville rests on Pleistocene gravel, as does also Goodyear's Bar. There are narrow areas of these old gravels also extending for several miles along the branches of the North Fork of the Yuba north of Downieville.

EVIDENCES OF GLACIERS.

The ridge in the northern part of the area known as the Grizzly Mountains supported a few small glaciers on its eastern slope, but there appears to be no evidence of glacial action on the western and southern

THE SIERRA BUTTES, SHOWING THE GLACIATED SURFACE AND THE BEGINNING OF A MORAINE.

slopes. Hough's Peak is one of the high points of this ridge, lying north of the fortieth parallel. Crystal Lake, which is on the north slope of this point, owes its origin to a terminal moraine. Another smaller terminal moraine was noted at the east base of a bluff that lies east of the peak. On the steep east slope of the ridge at Tower Peak there are several crescentic masses of morainal material, and on the east side of Little Grizzly Creek, opposite the mouth of the stream which heads at Tower Rock, is a piled-up mass of quartz-porphyry and greenstone bowlders that appears to be a terminal moraine.

Much the finest glacial district, however, is that of the ridge joining the Sierra Buttes and Eureka Peak. The east slope of the buttes and the névé basins about Gold, Bear, Wade, and the Jamison lakes are well polished and scored. So also is the north slope of Eureka Peak, the moraines on the lower east and north slopes of which are very interesting, showing by their forms especially well the course of the glaciers. Eureka Lake is a reservoir, the construction of which was made easy by the manner in which the moraines surround it, forming a natural basin, open only to the north. A medial moraine runs from the moraine on the east side down the slope in an easterly direction, forming the backbone of the side ridge north of Johnsville. In this moraine are abundant bowlders of gabbro from the area on the east slope of Eureka Peak. The terrace on which Johnsville is situated shows stratification in its upper layers. All about Johnsville are enormous accumulations of morainal material. Over an area of 15 square miles none of the underlying formations are exposed. On Frazier Creek, and at other points, this moraine stuff has a depth of 700 feet. The bowlders are chiefly of quartz-porphyry and greenstone, from the extensive areas of these rocks in the névé region of Eureka Peak, Mount Elwell, and Gold Lake. This morainal area merges on the east into the terraces formed by a Pleistocene lake that appears to have filled the Mohawk Valley at the time the glaciers were in existence. Opposite Jamison, on the east side of Jamison Creek, there is an exposure of the moraine material at the point where the highest lake terrace begins. The underlying coarse gravel and subangular material are roughly stratified. In the bed of Jamison Creek, just below the bridge at Jamison, a shaft was sunk some years ago to the depth of 270 feet, all in gravel. This shaft is still to be seen. There must therefore be a great thickness of detrital material here.[1]

The sharpness of the line separating the bare glaciated surfaces of the rocks that were covered with glacial ice and the morainal material is rather remarkable in this region. Plate XXII, from a photograph of the northeast slope of the Sierra Buttes, is intended to illustrate this fact. The lake shown is the lower Sardine Lake. From the upper (west) end of this lake to near the top of the buttes all is bare glaciated rock, with only occasional bowlders. The morainal material of the

[1] Bull. Phil. Soc. Wash., Vol. XI, p. 393.

moraine south of this canyon begins at the west end of the lake, and extends diagonally up the ridge south of the lake, and from that line northeasterly the ridge is composed entirely of glacial débris. The white material west of the lake is a reservoir of finely comminuted quartz from the mill of the Young America quartz mine, which formerly operated farther up the canyon.

Another interesting feature is brought out in Plate XXIII. The long moraine here shown is the same as that just described beginning just south of the lower Sardine Lake. It has cut across an older moraine, which had a more nearly north-and-south trend, and appears to have been formerly a glacier moving down the drainage from the Salmon lakes basin. The white level lines on these moraines are ditches and roads. There is practically one continuous sheet of moraine material from Gold Lake to the southeast slope of the Sierra Buttes. All of the level land east of Gold Lake, known as Church Meadows, appears to be underlain by moraine stuff. The valleys of the streams to the west of the high ridge of the Sierra Buttes and Eureka Peak likewise formerly contained glaciers, the one in the canyon of the East Fork of the North Fork of the Yuba originating north of Gold Valley and at one time filling that valley, the bottom of which is covered with ground moraine, and the one filling the canyon of the Middle Fork of the North Fork originating about the Spencer lakes and the northeast slope of Rattlesnake Peak.

Sierra City is in part built on moraine material. There were likewise glaciers on the north slope of Deadman's Peak, in the canyon of the South Fork of the North Fork of the Yuba, and at the head of the Middle Fork of the Yuba at Milton, and elsewhere. Small glaciers existed at Pilot Peak and at the head of Nelson Creek, and there is some morai e-like débris west of the Blue Nose Ridge.

In 1890 morainal stuff was being mined on Poor Man's Creek, northeast of Pilot Peak, by the hydraulic method. The gold was mostly angular, and came chiefly from a white dike of Tertiary quartz-porphyry or rhyolite.[1]

On the slope west of Mohawk Valley, two miles south of Wash post-office, is Bennett's hydraulic gold gravel mine. The bed rock is granite. On the north side of the ravine the material lying on the granite is seen to be made up of clay considerably compacted, with numerous pebbles and bowlders, which are generally well rounded. On some of them scratches were evident. The upper material was composed of sand and gravel, with many fragments of granite, and of pre-Cretaceous and Tertiary volcanic rocks. Traces of a rough stratification were noted. The material is supposed to be part of the higher terraces of the Pleistocene Mohawk Lake, and to have been furnished by the glaciers on the slope above, and therefore to be partly morainal.

Four miles due west from the summit of Mount Ingalls, on the top of

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[1] Am. Jour. Sci., Vol. XLVII, p. 473.

OLDER MORAINE CUT ACROSS BY A YOUNGER MORAINE.

the ridge east of Little Grizzly Creek, is an area of andesitic breccia, at the south end of which is a small mass of the dense older basalt. Lying on the andesite and on the underlying Carboniferous rocks of the east slope of the ridge is a moraine-like mass of rubble, including many granite bowlders, and some of the older basalt which may easily have come from the small area on the ridge just south of the andesite. The granite bowlders are particularly abundant northeast of the north end of the andesite area They may have been formerly embedded in the fragmental andesite, although their distribution suggests strongly a morainal origin. A glance at the geologic map, however, will show that this origin is difficult to explain, unless the moraine (?) be supposed to exist before the eruptions of the basalt that forms the upper half of the mountain. There is no granite exposed in the drainage basin on the flank of which the moraine-like mass is situated, but the granite area of the west slope of Mount Ingalls extends under the basalt, and may have been exposed at the head of the drainage basin here described before the basaltic eruption. Glaciers certainly existed on Mount Ingalls after the basaltic eruptions, for there are glacial striæ on the basalt in the basin on the east slope, 1½ miles south of the summit, and just below is a pond formed by a small terminal moraine. In a ravine on the steep north slope of the high ridge north of Eureka Peak, at a point about 4¼ miles northwest of Johnsville, is a small terminal moraine. The summit of the ridge south of the ravine has an elevation of 7,000 feet.

PLEISTOCENE LAKE BEDS.

Mohawk Valley[1] in Pleistocene time was the bed of a considerable lake. This is testified to by a series of terraces of gravel and sand, best seen on the west side of the valley. The highest of these have an elevation of about 5,100 feet. Lower terraces are to be seen at numerous points in the valley. The lake at its highest level not only filled Mohawk Valley, but extended east into Humbug Valley, having a surface of about 35 square miles. The deposits at the highest stage were largely rather fine material, andesite and morainal detritus, which has since been much eroded, particularly on the east side of Mohawk Valley, where well-defined terraces are not to be found. The best-preserved terraces are crossed by the road from Mohawk post-office to Johnsville. These are now heavily wooded. Exposures at various points show them to be composed of loose sand and gravel, distinctly stratified, the bedding being approximately horizontal. Pebbles of andesite and rhyolite abound in the lake beds, and to the north and east of Mohawk Valley thin patches of lake deposit may be seen at many points, resting on andesite tuff. It is therefore certain that the lake attained its maximum development after these andesitic eruptions. Moreover, the eruption of the andesite appears to have been the cause

[1] See Mohawk lake beds: Bull. Philos. Soc. Washington, Vol. XI, p. 385.

of the formation of the lake. Judging from the present contours of the surface of the pre-Cretaceous formations (granite and the Auriferous slate series), the Middle Fork of the Feather River follows approximately an older drainage system, which existed before the later volcanic eruptions, though perhaps not for a great length of time. These eruptions, largely of fragmental andesite, filled up the drainage that then existed, and the waters thus dammed back formed the Pleistocene lake of Mohawk and Humbug valleys. Since that time the river has cut through the barrier and the lake has been drained. For three miles north of the Mohawk Lake beds the Feather River of the present time flows through a canyon whose walls and bottom are composed entirely of andesitic material.

Forming a set of terraces in Mohawk Valley, about 4,500 feet in elevation and well exposed along the Feather River where it enters the valley from the east, and by the public road south of Wash post-office, are beds of coarse gravel and sand containing pebbles of the late olivine basalt, like that on Penman Peak. This basalt is of later age than the andesite breccia. These low terraces appear to represent a late stage of the Pleistocene lake. They rest unconformably on an older series of fine sediments of Tertiary age, as may be seen in Pl. XXIV, which was made from a photograph of an exposure on the west side of the river one-fourth mile down stream (north) from Mohawk post-office.

On the east bank of the river, the material of the 4,500-foot terrace east of Wash post-office shows two small faults, and the fissures along these faults are now filled with sand, forming veritable little sand dikes. Other evidence of faulting is presented in a preceding paragraph. The water in the Mohawk Lake must have had a depth at one time of more than 500 feet.

TERTIARY LAKE BEDS

Underlying the Pleistocene beds of Mohawk Valley are a series of fine sediments, chiefly white shales with some carbonaceous layers. The beds are finely exposed along the Feather River north of Mohawk post-office, as may be seen in Plate XXIV, which represents both the Tertiary beds and the overlying Pleistocene gravels. The illustration also shows that the older beds have been eroded before the deposition of the late coarse gravelly material. Embedded in the Pleistocene gravel and sand are angular blocks of the Tertiary shale. The same Tertiary beds may be seen at numerous points in Mohawk Valley. What are probably portions of the beds of the same Tertiary lake are exposed along the Feather River east of the valley on the farm of Abel Jackson.[1] Fossil leaves were obtained here at two points, and a list of some of these may be found in the previous report.[2] Other material was obtained later, which has not yet been studied. Oak leaves are abundant. Professor

[1] It is likely, however, that the leaf beds at Jackson's are later than the white beds containing layers of carbonaceous shale.

[2] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894 p 466, and Mohawk lake beds, p. 39!

MOHAWK LAKE BEDS, SHOWING UNCONFORMITY OF THE PLEISTOCENE GRAVELLY BEDS ON THE TERTIARY BEDS.

Knowlton considers the deposit to be of Tertiary age. The beds at locality 115 are covered by andesitic breccia, and the upper layers of shale were so intercalated with andesitic material as to indicate that the andesite eruptions had begun at the time the leaf beds were forming. The beds at locality 114 (about 1,000 feet up stream from 115) are made up of sandy material with layers of Carbonaceous shale, resting on pre-Cretaceous stratified tuffs. Only one species was recognized here—*Platanus dissecta?* Lx. The beds dip westerly at a gentle angle. There appears to have been erosion before the beds were buried under the andesitic breccia, as they are distinctly cut off to the south by the unstratified breccia, which reaches down to the level of the water. About one-fourth mile upstream, around a sharp bend of the river, are some beds of granite detritus, also covered by the andesite breccia. This detritus is probably another exposure of the beds seen at locality 114.

On Grey Eagle Creek, about 1½ miles nearly south of Mohawk post-office, at an elevation of about 4,600 feet, is another exposure of beds very similar to the older beds shown in Pl. XXIV, consisting of beds of clay and sand with layers of carbonaceous shale. In addition, there was observed a fine white layer, a few inches in thickness, composed almost entirely of volcanic glass in angular fragments, with fluted forms, very similar to some material described as volcanic dust by Mr. G. P. Merrill.[1] The most reasonable explanation of the homogeneity of the volcanic layer is to suppose that it was thrown out in its present fine condition and, falling in the water, was deposited as we now find it. It might also be supposed that it was eroded from an area of volcanic ash near by and redeposited on the lake bottom, and indeed there is a considerable area of rhyolite near by. The angular character of the dust is against its having undergone much transportation except in the air, though fine thin glass would doubtless be not greatly rounded, but rather broken into finer angular particles. The material presents all the appearance of being rhyolitic glass. This is further substantiated by a silica determination made by Dr. W. H. Melville, of the United States Geological Survey. He found the white powder from Grey Eagle Creek to contain 70.64 per cent of silica. Whether this layer of volcanic dust had its origin in the rhyolitic eruptions that may have had their source in Haskell Peak or in the much more recent eruptions of Lassen Peak is not apparent.

EOCENE RIVER GRAVELS.

The Neocene rivers of the eastern part of the Downieville district do not seem to have had any connection with those of the western part, and it is probable that a ridge existed between the two systems.

[1] Merrill, G. P., Deposits of volcanic dust and sand in southwestern Nebraska: Proc. U. S. Nat. Museum, 1885, pp. 99–100.

THE OLDER WHITE QUARTZ GRAVELS.

The white quartz gravel channel of Camptonville and Depot Hill, which is east of Oak Valley, in the Smartsville area, first appears in the Downieville district at Indian Hill, where it was formerly extensively hydraulicked. It was there at one time covered with andesitic breccia, a remnant of which is still preserved on the summit of the hill. The next trace of the channel is in the Bidwell Bar area at Grizzly Hill, Brandy City, and Council Hill, and it reappears in the Downieville district south of Scales. From there to Mount Pleasant and Poverty Hill the gravel beds may be followed continuously. This channel and its two main branches are the only old river channels that can be followed for any long distance in the Downieville area. Much information about them is to be found in Professor Pettee's report in Whitney's Auriferous Gravels. A few notes that give some information additional to that in the above report are here given. The channel appears to fork north of Scales, one fork extending to Poverty Hill and the other to Mount Pleasant and north under the lava. The Poverty Hill branch appears on the north side of Slate Creek at Barnards Diggings, and then successively at Secret Diggings, Laporte, Thistle Shaft, Gibsonville, Whisky Diggings, and Hepsidam, where it has been followed through the ridge under the lava, and thence into the air, as Professor Pettee puts it.

At Poverty Hill some leaf impressions were found about one-half mile southwest of the village[1] in fine sediment, undoubtedly part of the river gravel series. The leaves were referred to Professor Knowlton, who reported: "They seem to belong to the Cupuliferæ, but beyond this it is impossible to venture."[2] The gravel deposits of Laporte and vicinity were studied quite extensively by Professor Pettee, who was much aided by Mr. C. W. Hendel, who had made many notes while the mines were being operated. There appears to be good evidence of faulting in the gravel beds, and the lens of bed rock (amphibolite-schist) shown in the gravel area on the geologic map seemed to the writer to represent an upraised mass. The reader is referred to Professor Pettee's report for many interesting details.

To the east of the main mass of white quartz gravel, where the road to St. Louis leaves the Gibsonville road, is a considerable amount of "bastard" gravel. It is sometimes called bench gravel, and is believed here, as at other points, to have been deposited at a much later time than the quartz gravel.

The "bastard" gravel is quite like that noted north of Lexington Hill, in the Bidwell Bar area. It appears without doubt to have been at one time covered by the andesite, as it forms part of the sandy layers that may be seen to extend under the andesitic breccia by the ditch on the south side of the road.

[1] This leaf locality is, therefore, in the Bidwell Bar area.

[2] Am. Geologist, Vol. XV, p. 377.

The white quartz gravel at Laporte may have come in part from quartz veins immediately adjacent, and which may be seen there still in the bed of the old river.

The channel between Laporte and Gibsonville is covered with andesitic breccia. There is no doubt, however, of the existence of the river deposit under this lava, as it has been penetrated at the Thistle shaft, about 4 miles northeast of Laporte, and the gravel is now being mined there. The Yankee Hill gravel at the south edge of the andesite-breccia area is perhaps a part of the Laporte Channel, but there is some doubt about it. According to Mr. Quigley, of Little Grass Valley, a basalt column was found at Gibsonville in the gravel, which at the top spread out umbrella-like over the gravel. There is to be seen at the present time an area of late olivine basalt at the north border of the gravel area, a little west of Whisky Diggings. From Gibsonville the gravel may be followed continuously through Whisky Diggings to Hepsidam, where the channel disappears under the lava. From Laporte to Gibsonville the average present grade of the bed of the Neocene river is about 80 feet to the mile; from Gibsonville to Whisky Diggings, about 250 feet to the mile; and from the latter place to Hepsidam, a distance of over a mile, about 400 feet to the mile. The measurements, while not accurate, have a comparative value, and as the character of the gravel and the old channel does not appear to have changed in this distance, the rapid increase in grade is in all probability to be ascribed to a subsequent differential elevation toward the east. Mr. W. Lindgren, who visited Hepsidam in 1887, when the continuation of the river channel under the andesite breccia was being mined by means of a tunnel (the Niagara Consolidated Mine), writes:

> From Hepsidam up to the present workings (in the tunnel) the channel rises about 150 feet in 3,900 feet, horizontal distance. Under the summit of the ridge a sudden drop of 50 feet in the channel was met with, which necessitated a new tunnel. The gravel was sharply cut off. The channel was perhaps 800 feet broad.

Near Hepsidam more or less of the gravel has been consolidated into an iron-stained quartz-conglomerate. According to Mr. Lindgren the space between the gravel and the fragmental andesite of the ridge top is occupied by a heavy bed of pipe clay, extending along the road up to and above Hepsidam Camp. The superintendent of the Niagara Consolidated Mine stated that dikes of hard lava were encountered in the tunnel.

On the other (eastern) side of the ridge the bed rock at the present time sinks rapidly toward the Feather River. The Bunker Hill tunnel, on the east side of the ridge, working westerly, is said to be on the same channel. From there east no other gravel deposits that can with any certainty be ascribed to this channel are known to exist, but at the north and west base of Blue Nose, at the edge of the lava, about 500 feet below the Bunker Hill tunnel, are two masses of white quartz gravel that may be downthrown portions of the Hepsidam river deposit. That extensive faulting has occurred there can be no doubt, and that the region about Blue Nose is one of enormous former volcanic activity, where the lavas issued, is also apparent. Much of the lava here is massive andesite, in part dikes occupying fissures in the bed rock. A little over a mile northeast of Mount Fillmore is considerable gravel under the andesite, and both are cut by basalt dikes (No. 11 Plumas).

The other branch of the Neocene river just described is well exposed about Mount Pleasant. There is also between this point and Poverty Hill a large amount of so-called "bastard" gravel, forming little wooded ridges just south of the fragmental lava of the ridge to the north. At the Iowa shaft north of Mount Pleasant this old channel was formerly mined, and it is likely that this mine will be reopened. The next appearance of the gravel is on the north side of the volcanic ridge about one-half mile southwest of Port Wine. The claim is called the Bunker Hill, and should not be confused with other mines of the same name in the Downieville area. Here a tunnel is being run in under the lava. The Lucky Hill mine occupies some of the intermediate ground of the volcanic-capped ridge between the Iowa shaft and the Bunker Hill. This property is as yet undeveloped, but such work as has been done indicates that there is a channel under the andesitic breccia, which connects with the Iowa Hill gravel. At Port Wine, where the deposit is next to be seen, there were very abundant dikes of basalt cutting the gravel, and some of these may still be seen just south of the village and east of the road. From Port Wine the channel has been almost continuously mined through Queen City, Grass Flat, Gardeners Point, Cedar Grove Ravine, St. Louis, Pine Grove, and Howland Flat. To the northwest of the latter place and to the west of the road there are some fine exposures of the gravel beds, showing, by their irregular upper surface, that they were considerably eroded before being covered by the fragmental andesite. Mr. Ruep, of San Francisco, who was formerly interested in the Howland Flat mines, states that a drift in the Hibernia gravel claim, 200 feet below the town of Howland Flat, came squarely up against a wall of compact lava like that forming the point on the ridge to the south known as Table Rock. This is a very fine grained hornblende pyroxene-andesite (No. 263 S. N.). Mr. Ruep estimated that this drift struck the lava wall 1,700 feet below the summit of Table Rock, and supposed it to be a part of the same mass as Table Rock. There was said to be 600 feet of pipe clay over the gravel at Howland Flat where not eroded. On the slope south of Table Rock, in a ravine draining into Canyon Creek, are the California Diggings. According to Mr. Ruep only the lava wall of Table Rock separates this river gravel from that of Howland Flat, and if, as seems likely, the Deadwood gravel on the south side of Canyon Creek was formerly connected with the California Diggings, the elevation of both being about 6,000 feet, this smaller channel may be regarded as a branch of the

Howland Flat River. The channel of Potosi (elevation about 5,800 feet) was followed in under the lava. At the time of Professor Pettee's visit the continuation of the channel was not known, but he expressed the opinion that it extended under the ridge to Cold Canyon, on the slope toward Poker Flat. This has since been verified. The channel was followed in by tunnels. According to Mr. Ruep the gravel beds were much broken up, some masses being 50 feet above other masses. According to Mr. Lindgren there is said to have been a rise in the channel up to the middle of the ridge, then a fall, until at Cold Canyon the elevation is about that at Howland Flat. This rise and fall was not, however, gradual, but by steps, the channel being suddenly cut off at several points by polished and striated walls, evidently fault surfaces. The source of the channel east of Cold Canyon is unknown. Much and perhaps all of it is now eroded.

At Studhorse Canyon, below Cold Canyon, is a mass of detached gravel, which is possibly a displaced portion of the same deposit. The displaced character of the gravel is well seen at Bruckermann's tunnel, where the gravel stratum stands in a highly inclined position. Between the gravel and the bed rock is a dike of fine grained pyroxene-andesite.

The Deadwood channel has been followed about 1 mile by tunnels in under the lava in a southeasterly direction to a claim known as Bunker Hill. Numerous faults are said to have been encountered in the tunnel, and at one point a large quartz bowlder is said to have been cut in two along a fault, so that one part was found in the roof and the other in the floor of the tunnel. Numerous lava dikes were met with. The course of this channel to the east of Bunker Hill is not known.

There are some gravel deposits that have been mined by tunnels on the east side of the high ridge of which Table Rock is a part, about east of Port Wine. This has been called the Wahoo district.

A considerable river deposit has been extensively mined on the ridge east of Canyon Creek. It is well exposed at Morristown and Craig Flat. At the latter place the gravel shows evidence, by its very uneven upper surface, of having been eroded before being covered by the andesitic breccia. The very large gravel mass at Eureka, 1½ miles southeast of Craig Flat, is undoubtedly a part of the same river deposit. It may thence be traced to the ridge east of Eureka Creek, where it has also been mined, and thence across Goodyear Creek to the Monte Cristo and Excelsior mines. The course of the channel from here is a matter of pure conjecture; neither can it be asserted that the drainage was from Eureka to Monte Cristo. It may have been in the opposite direction, and, judging from the increased size of the gravel deposits at Eureka, this was probably the course of the stream.

On the summit of Craycroft's Ridge, east of Sailors Ravine, are three patches of gravel. Two of these, one 3½ and the other 4 miles northeasterly from Downieville, are composed largely of well-washed quartz gravel and are not capped with volcanic material. The third occurrence is on the east edge of an area of andesitic breccia 5 miles northeasterly from Downieville. At the time of my visit (1893) this deposit was being mined by the Wide Awake Drift Mining Company.

Six and three-fourths miles north of Downieville, just north of Rattlesnake Creek, is a small deposit of gravel known as Rattlesnake Diggings. The following notes concerning it are from a report by Mr. Lindgren. The elevation of the locality is approximately 5,500 feet; underlying the gravel is a bed of rather fine-grained volcanic tuff containing many well-rounded particles. This forms part of the bed of Rattlesnake Creek for about one-half mile above the mouth of the run that joins Rattlesnake Creek just west of the diggings. To the west, south, and north the bed rock (clay-slates, etc.) rises several hundred feet. To the north the volcanic material is continued up to the large area forming the high Rattlesnake Peak Ridge. The gravel is subangular and evidently was formed in a small water course. Whether the present position of the gravel and tuff is due to displacement or other cause was not ascertained. The gravel was washed by the hydraulic method.

One-half mile southeast of Rattlesnake Peak, at the edge of the volcanic area, is the tunnel of the Red Oak gravel mine.

According to Pettee[1] the gravel of the Laporte area is cut off under Bald Mountain by a wall of gray lava (andesite). Underlying the alluvium of Little Grass Valley, 2 miles northwest of Bald Mountain, is a considerable body of white quartz gravel, which has been much exploited by Mr. Quigley. From its peculiar position, underneath the drainage of the South Fork of the Feather River, it has not been practicable to mine it profitably on account of the excess of water. Mr. Quigley believes this channel to continue under Grass Valley Hill, and thence northeasterly under the lava to Richmond Hill and Sawpit, northwest of Onion Valley, and so far as present information goes this is not impossible. The white quartz gravel underlying Little Grass Valley is not all thoroughly rounded, and this is also true of the gravel at Richmond Hill and Laporte.

Two and a half miles west of the Richmond Hill gravel area, at the south edge of the andesitic breccia and on the slope north of Onion Valley Creek, there is some river gravel along a ditch. The pebbles are of the pre-Cretaceous rocks and of Tertiary lavas. Granitoid pebbles of large size are abundant. These may, however, be of local origin, as there are granitoid dikes here in the serpentine. The occurrence would otherwise be very remarkable, as no granite areas are known anywhere in the neighborhood.

At Richmond Hill hydraulic mine there is no lava on the gravel, but the extension of the same area to the east is covered by andesitic

[1] Auriferous Gravels, p. 446.

breccia, and on the east side of the breccia the Union Hill gravel mine is on the same channel. The latter mine has been worked by the hydraulic method just east of the road to Onion Valley. Some poor leaf impressions were noted in clay at the Union Hill deposit, and here is also some of the iron-stained quartz-conglomerate noted before. The Union Hill mine is about one-half mile north of Onion Valley.

Two and a half miles northwest of Onion Valley, on the north edge of the andesitic breccia area, on the slope toward the Middle Fork of the Feather River, is an area of gravel on serpentine bed rock. The quartz conglomerate occurs here also. Immediately west is an area of the older basalt, which extends lower down on the slope than does the gravel.

At Sawpit there is said to be white quartz gravel under the black basalt. If so, the deposit is undoubtedly part of the Richmond Hill–Union Hill channel.

The following record of bores made by the Feather Fork Gold Gravel Company was kindly furnished by Mr. R. Stevenson, of Laporte. The bores were made for the purpose of finding gravel channels under the lava and are located in Mr. Stevenson's notes by reference to land sections. The locations given by distance from definite points were estimated by the writer from the California State engineer's map.

Two bores were made almost on a diagonal line from the southwest corner to the northeast corner, or about 3 miles west of Pilot Peak, on the ridge north of the South Fork of the Feather River.

Bores in sec. 12, T. 22 N., R. 9 E.

	Feet.
Bore 1:	
Pipe clay	91
Quartz gravel	4.5
Total	95.5
Slate (?) bed rock.	
Bore 2:	
Hard lava	60
Soft lava	74
Lava bowlders	41
Soft lava	84.5
Sediment and blue pipe clay	6
Gravel, lava and quartz	3
Total	268.5
Serpentine bed rock.	

Three bores were made about half a mile northwest of Laporte, with the results shown in the following table:

Bores in the NW. ¼, the SE. ¼, sec. 9, T. 21 N., R. 9 E., or about one-half mile northwest of Laporte.

	Feet.
Bore 1:	
Surface lava and loam	20
Quicksand	32
Red and blue clay	54
Bogus gravel (white)	2
Blue pipe clay	11
Blue quartz sand containing gold	6
White and blue quartz gravel	15
Total	140
Light-blue bed rock, with quartz seams.	
Bore 2:	
Lava clay	20
White quartz sand	2
Pipe clay	4
Coal (lignite)	4.5
Red pipe clay	143.5
Quartz gravel containing gold	17
Total	191
Blue bed rock.	
Bore 3:	
Surface loam	4
Pipe clay	17
Coal (lignite)	3.5
Red pipe clay	145.5
Gravel and clay	14.5
Total	184.5
Soft blue bed rock.	

A bore was made about a quarter of a mile northwest of Laporte, with results as follows:

Bore in the SW. ¼, sec. 5, T. 21 N., R. 9 E., about one-fourth of a mile northwest of Laporte, in the Bald Mountain ridge.

	Feet.
Surface loam	4
Gray lava (andesitic breccia)	114.5
Gray lava (clay)	7
Bogus gravel or river wash	3.5
Total	129
Greenish bed rock (amphibolite schist).	

A bore was made where the Little Grass Valley road crosses the Feather River ditch, almost on the north section line, or about 1½ miles northeast of Laporte, with the following results:

Bore in the NW. ¼, sec. 10, T. 21 N., R. 9 E.

	Feet.
Surface lava (soft)	26
Gray lava (andesite), hard	119
Pipe clay	1
Black lava (probably the older basalt)	120
Light lava sand	2
Dark-brown hard lava (basalt?)	39
Quartz gravel and clay	124.5
Hard quartz gravel, containing gold	4.5
Total	436
Soft blue bed rock.	

Another bore was made on the ridge northwest of Sawpit in the NE. ¼ of the NW ¼ of sec. 36, T. 23 N., R. 9 E. This penetrated 340 feet of volcanic material. Mr. Stevenson thought the appearance indicated an eruptive dike from which gray and black lavas have issued through all the ridge between the Middle Fork of the Feather River and Onion Valley Creek.

MISCELLANEOUS GRAVEL DEPOSITS.

A considerable number of remnants of old river channels have been noted, concerning which the writer has very meager information, and they are therefore grouped under the above heading. Some of these doubtless represent the writer's intermediate period.

On the north side of the Middle Fork of the Feather River, about one-half mile west of Nelson Point, is a gravel deposit that was formerly mined by the hydraulic method. Andesitic breccia occurs on the slope to the north and presumably at one time covered the deposit. The occurrence is remarkable as being only about 200 (?) feet above the present Feather River. On the south slope of Clermont Hill, near the summit, at an elevation of about 6,400 feet, an English company exploited a gravel channel that is covered by andesitic breccia. The gravel seen by the writer at the mouth of the tunnel was chiefly of quartz and other siliceous rocks and was largely subangular in character, indicating a small water course. The gravel is said to have contained a good deal of gold in spots. A miner informed me that a mortar and pestle were obtained years ago from the andesitic breccia overlying the gravel. The miner was very positive that the implements were found in the volcanic material, which is said also to contain fossil wood. Some blackened wood was found by the writer on the dump of a shallow shaft in andesitic breccia, a little southwest of the cabins belonging to the gravel mine. The present owner of the mine stated that this certainly came from the andesitic breccia. The specimens were referred to Professor Knowlton, who reported as follows:

> It is coniferous and appears to have come from the root. When examined in radial section the wood cells are seen to be long, sharp pointed, and provided with a single row of very minute pits. The medullary rays are seen to be long. In tangential section showing the ends of the medullary rays, they are found to be very small, and in a single vertical series, and from one to four, usually two or three, cells high. This wood has the appearance of being very recent, but I am unable at present to refer it to any species with which I am familiar. It is probably a cedar and may belong to the genus Chamecypario, but it is unlike either of the species of this genus of which I have specimens.

On the steep east slope of the ridge, 4½ miles northeast of Johnsville, is Miller's lower tunnel. The altitude is about 6,500 feet. In 1890 this tunnel had penetrated a gravel deposit under the ridge, capped with andesite breccia. The material seen was subangular and contained small fragments of blackened wood. A curious feature of the deposit was a layer composed of brown grains cemented by a white substance. The microscope shows the brown grains (No. 377 Plumas) to be microlithic fragments containing feldspar laths, augite grains, and very abundant prisms of olivine. The layer is, therefore, a basaltic tuff. The white cementing material is opaque and appears to be clay. No such basaltic tuff has been noted by the writer at any other locality under andesite. The bottom of the Miller gravel channel is about 400 feet vertically under the top of the ridge. It evidently represents a deposit of gulch gravel.

The Blue Lead gravel mine is on the ridge north of Poormans Creek, 2½ miles northeast of Pilot Peak. There is white quartz gravel here with a rubble of andesitic bowlders on top, like the massive andesite of the area immediately west. A piece of wood was given the writer as coming from this claim by the owner, Mr. Thomas. The wood is firm and not silicified, and is dark in color. Whether the specimen came from the andesite rubble or from the gravel is uncertain, but probably from the former.

On the ridge north of Indian Valley and east of Canyon Creek are a number of gravel deposits at the edge of the large andesitic breccia area capping the ridge. These may be parts of a single subordinate channel. The most southern occurrence is at the Rocky Peak drift mine, about 2 miles north of Indian Valley; the next is on the west side of the volcanic cap at Bunker Hill; another area is at the Sailor Boy diggings, and the most northern is just west of McMahon's. The gravel at all these points is more or less similar, the pebbles being of dark quartzite, siliceous schist, and of Tertiary lavas. At McMahon's the lowest gravel is chiefly of white quartz, the pebbles of which are usually 3 inches or more in length, and there are in addition the same pebbles as noted above. The elevation at McMahon's is less than 5,000 feet, and the other masses noted lie at a successively lower level going south, until at Rocky Peak mine the elevation is only about 4,000 feet. The course of the channel is probably therefore southerly. There is no likelihood of any connection of the McMahon gravel with the large channel at Eureka, as higher bed rock intervenes, but it is not impossible that the McMahon channel may have joined that at Scales, although the character of the gravel indicates that it is part of the Sailor Boy channel.

There are gravels under the fragmental andesite on the high ridge south of Downieville. They were mined by a shaft at the Pliocene mine, and by a tunnel at the Ruby mine, north of Table Mountain, in a ravine draining into Rock Creek. Two distinct channels have been found, one, the older, extending toward the Bald Mountain extension mine channel, but not certainly connected with it. The younger channel lies 116 feet lower and connects with the old Rock Creek diggings and with those at the City of Six. At the head of Slug Canyon is the City of Six gravel deposit. The material exposed is 500 feet wide and one-third of a mile long. The pebbles are of quartz and of the older metamorphic and igneous rocks. This channel was tunneled through to Rock Creek. The channel of the Bald Mountain extension mine has been extensively worked from tunnels that start in on the south slope of the ridge. The Nebraska diggings are on the north slope of the ridge, $2\frac{1}{4}$ miles southeasterly from the Pliocene shaft, and in the drainage of the Jim Crow Ravine. The gravel has been extensively mined. It extends under the andesite breccia.

The Sierra Buttes are the culminating points of the highest ridge in the Downieville area, the topmost point having an altitude of 8,615 feet. The ridge gradually decreases in altitude to the northwest, but for 17 miles many points on the summit are 7,000 feet or more in elevation. To the north of the Feather River the Grizzly Mountains form another high ridge with northwesterly trend, Tower Rock near the north end of the ridge having an elevation of 7,795 feet. Both of the ridges are made up chiefly of pre-Cretaceous rocks. To the east of these two high ridges there appears to have been in Neocene time a north-and-south river system, remnants of which are still preserved at a considerable number of points. Commencing on the north we find north of the fortieth parallel (Honey Lake Sheet), on the ridge east of Little Grizzly Creek, at elevations of from 5,500 to 5,800 feet, three masses of river gravels. South of the fortieth parallel (Downieville Sheet) the gravel is first seen on two spurs of the Grizzly Mountain about 2½ miles southeast of Tower Rock. Two miles farther southeast, at the Cascade gravel mine, the river deposits may again be noted, and immediately south of this mine is another gravel area that has not yet been mined. The average elevation of all of these gravel masses is about 6,000 feet. Pl. XXV represents an exposure of the beds at the Cascade hydraulic mine. The oblique line to the right in the gravel probably indicates a line of displacement. Sandy layers are to be seen interstratified with the gravel. The thickness of this river deposit is about 325 feet. There are large granite bowlders in the gravel, which presumably came from the granite area immediately to the south. The bed rock of the mine is the Auriferous slate series, in which were noted numerous dikes. The occurrence of the granite bowlders to the north of their source, although but a short distance, may be regarded as evidence that the river drained to the north. Carbonized and blackened wood (Nos. 205–206 Plumas) occurs in the gravel at the Cascade mine.

The two bodies of gravel last noted lie on the edge of the large area of andesitic breccia that forms the upper portion of the southern part of the Grizzly Mountains. There is little doubt that the channel extends under the lava and reappears on the south border of the area on the spur north of Little Long Valley Creek, where the elevation of the gravel is from 5,600 to 6,000 feet, according to the topographic map. The large area at the south end of this spur has been hydraulicked. Going south the gravel of this ancient river is next to be seen about Lava Peak, and then on the spur south of Long Valley Creek, some of the gravel at the latter locality having an elevation of only 5,000 feet. At the north end of the Mohawk Lake beds is an area of well-rounded gravels, composed of pebbles of the pre-Cretaceous rocks. This deposit rests, where surely in place, on the auriferous slate series. The low altitude (about 4,500 feet) of a portion of this gravel at the mouth of Cedar Creek is probably due to landslides, for where it is certainly in place on the ridge south of Cedar Creek the maximum elevation is 5,500 feet, extending down the ridge slope (easterly) to near the 5,000-foot contour. A tunnel by the Feather River at the mouth of Cedar Creek has been run in to strike this gravel channel, but if landslides have occurred here, it is evident that the tunnel is much too low (4,400 feet). The tunnel, according to a miner at work there, was 1,800 feet long in 1890, and was in hard lava all the way. The hard lava referred

NEOCENE RIVER GRAVELS AT THE CASCADE GRAVEL MINE.

to is the andesitic breccia that forms the bed and walls of the river in this vicinity. A shaft was sunk on the hill top 500 feet above and east of the tunnel's mouth. It is said that this shaft was in gravel for its entire depth, or 375 feet. As indicated above, however, all of the gravel below the 5,000-foot contour is believed to be out of place. This downthrown material is, however, not all gravel. There is some andesitic breccia mixed with it. Numerous rhyolite bowlders and pebbles indicate an area of that rock in the vicinity now eroded or covered over. The presence of these rhyolite pebbles would seem to indicate that a portion of this gravel is of later age than that of the Haskell Peak channel, which is capped with rhyolite.

So far as could be made out, the Cedar Creek river gravel is in immediate contact on the south with the Pleistocene Mohawk Lake beds. The deposits of the old river channel just described, extending from north of the fortieth parallel near Little Grizzly Creek to the north end of the Mohawk Lake beds, are similar in being made up of gravel and coarse sand with very little fine sediment. This may be taken as evidence that this river bed had a higher grade than those of the southwesterly system of the western half of the Downieville area.

The next gravel area to the east of the high Sierra Buttes is on the steep granite slope south of Mohawk Valley, where it has an elevation of 7,000 or more feet. A large portion of this gravel mass has, however, gravitated down the slope, and some of it lies at an elevation of only 6,600 feet. Overlying the gravel is rhyolite. This channel is next exposed on the rhyolite-capped spur 1¼ miles north of Haskell Peak, where there is a layer of fine loose sediment overlying the gravel. Here is found a considerable variety of pebbles, and a collection of these was made. A microscopic study of the pebbles (No. 196 Sierra Co.) shows that the following rocks are represented: Contact metamorphic schist, granite-porphyry, an altered glassy andesite (?) showing flow structure, an altered holocrystalline basalt, a variegated breccia (red and green) made up of microlitic fragments and therefore a tuff, and a red fine-grained tuff. The two last are very similar indeed to some of the tuffs of the Milton formation. There is also a pebble of a lava which is so little altered as to make one doubt if it really came from under the rhyolite. It is a glassy microlitic lava containing hypersthene, augite, olivine, and some corroded quartzes, and strongly resembles a so-called quartz-andesite (No. 626 S. N.) of Tertiary age from the area two miles northwest of Downieville.[1]

As the bed rock of all the river gravels about Haskell Peak is granite, it is evident that all of these pebbles have traveled some distance, and the similarity of some of the pebbles to the rocks of the Milton series suggests that they may have been brought from the south, and that the next gravel bed to be described, that at Chips Hill, may be part of the same channel, for there the bed rock is the Milton series.

[1] Jour. of Geology, Vol. III, p. 410.

Chips Hill is on the south slope of the high ridge north of the South Fork of the North Fork of the Yuba River, 3 miles northeasterly from Sierra City. The elevation of the bed rock is about 6,500 feet. Rhyolite overlies the gravel, and is in turn covered with andesitic breccia. Just east of the Chips Hill gravel is a prominent south spur of the main ridge, and on the east side of this spur is another body of gravel at the edge of a narrow area of rhyolite, and this gravel may be connected under the ridge with the Chips Hill gravel. This eastern mass of gravel has a granite bed rock. The gravel about Haskell Peak is about 500 feet higher than that at Chips Hill, and if the drainage of this river was to the north it is plain that the Haskell Peak region has been differentially elevated. However this may be, the occurrence of a considerable body of river gravel on the edge of a high plateau, with a steep slope of more than 2,000 feet to the east and north, is very remarkable. There can be no reasonable doubt that a great displacement has occurred here, as noted under "Faulting." On the backbone of the ridge south of Sierra City, and about 3 miles southeast of that village, is a small amount of rhyolite, at the east edge of the large andesitic breccia area that caps most of the ridge. A little scattered river gravel is to be seen here, though it is obscured by the morainal material. The elevation is about 6,500 feet. It seems probable that here is a trace of the same channel as that at Chips Hill.

Two miles southeast of Milton is a very considerable mass of rhyolite lava, and on the west base of the andesitic breccia area that caps the ridge west of Tehuantepec Valley, 2½ miles east of Milton, is a long, narrow exposure of rhyolite. These rhyolitic areas may easily have been connected at one time and formed part of the flow that came down the Neocene basin to the East of English Mountain (Colfax sheet), and it is by no means impossible that this early Neocene drainage connected with that at Haskell Peak. About 2 miles east of the north end of Gold Lake is a small remnant of a Neocene river deposit, associated with rhyolite.

GRAVELS OF THE VOLCANIC PERIOD.

On the ridge north of the Middle Fork, northwest of Bells Bar, is an area of scattered gravel 2 miles long. The pebbles are largely of Tertiary volcanics, but there are also some of the pre-Cretaceous rocks. At an exposure at the west end of the area the pebbles are associated with, and partly scattered through, andesitic tuff. About three-fourths of a mile northwest of Spring Garden Ranch, just east of the road to Quincy, is a mass of volcanic gravel that has been mined by the hydraulic method. The gravel deposit known as Snowdon Hill is on the north side of Humbug Creek, 3 miles southwest of Goodyears Bar. The coarse gravel is chiefly andesite, but there are well-washed pebbles and bowlders of greenstone and porphyry, though not enough to note as a gravel area on the geologic map.

THE TERTIARY AND LATER VOLCANIC ERUPTIVES.

The Downieville area is remarkable as being in Tertiary time the theater of extensive volcanic eruptions. This region, indeed, is probably the chief source of the Tertiary volcanic materials of the Bidwell Bar area. The products of these volcanoes may be grouped under the following heads:

1. Rhyolite, both as a tuff and as a solid flow.
2. Basalt—
   - Older basalt, dense and black.
   - Doleritic basalt.
   - Late, dark, fine-grained, usually in dikes.
3. Andesite—
   - Hornblende-pyroxene-andesite, coarse-grained, usually a breccia or tuff.
   - Fine-grained hypersthene-andesite, late Neocene in age.

RHYOLITE.

The rhyolitic lavas are, so far as known to the writer, confined to the eastern part of the district. The most northern occurrence noted is 4 miles southeast of Mount Ingalls, where it has been exposed by the erosion of the andesite. There are two small areas southeasterly from Grizzly Peak and two north and one south of Humbug Valley.

The large rhyolite area 2 miles west of the Antelope House, in Mohawk Valley, is bordered on the east by the Pleistocene Mohawk Lake deposits, which contain abundant pebbles and fine débris of the rhyolite. Another small mass of rhyolite not shown on the geological map is north of the Middle Fork of the Feather River, 2 miles northeast of Wash post-office. This is overlain by the sediments of the Mohawk Pleistocene lake. As noted under "Tertiary lake beds," there is a layer of rhyolite glass (No. 160 Plumas) in the Tertiary beds, underlying the Pleistocene Mohawk Lake beds.

Two and a half miles northeast of Haskell Peak, on a spur west of the head of Mohawk Creek, is some rhyolite under the late doleritic basalt, at an elevation of about 5,500 feet. If this is regarded as having been a part of the Haskell Peak flow we have evidence here of this being a downthrown mass, and this might also apply to the other areas about Mohawk Valley.

The rhyolite of Haskell Peak attains a thickness on the north slope of nearly or quite 800 feet. In the top portion of the flow are numerous flattened oval cells, presumably steam cavities. It is capped by the late doleritic basalt; and at other points in the neighborhood by the andesite breccia. As has been stated under the heading "Neocene river gravels," rhyolite overlying gravel occurs 2 miles east of the north end of Gold Lake, about Haskell Peak, at Chips Hill, on the high ridge southeast of Sierra City, 2½ miles east, and 2 miles southeast of Milton. In the bed of Canyon Creek, 1½ miles up stream from Poker Flat, is a dike of rhyolite which forms the bed and east bank of the north branch that joins the creek at this point. It was traced up the south slope for 500 feet, where it disappears under the andesite that caps the ridge.

The following are analyses of rhyolites from the Downieville area. Partial analysis No. 1675 S. N. (A) was made by Messrs. Hillebrand and Steiger; No. 1675 S. N. (B) of the same specimen is taken from a complete analysis by Dr. Hillebrand; and the silica determination of No. 337 Plumas was made by the late Dr. W. H. Melville.

	No. 1675 S. N. (A).	No. 1675 S. N. (B).	No. 337 Plumas.
	Per cent.	*Per cent.*	*Per cent.*
Silica	71.39	72.70	71.14
Lime	1.01	1.15	....
Potassa	5.69	4.81	....
Soda	2.89	3.46	....

No. 1675 S. N. is from the area 2½ miles east of Penman Peak. No. 337 Plumas is from 2.2 miles southeast of the same point, but the amount of the material here is too small to indicate it on the geologic map.

BASALT.

The older basalt.—This dense, fine, and even grained lava is very similar in appearance and texture at all points seen. Except under the microscope, olivine is rarely to be detected. This mineral is, moreover, often altered to serpentine. The older basalt contains more magnetite than any other Tertiary lava in the Sierra Nevada so far as known. The largest area of this rock is about Red Clover Valley, in the northeast corner of the Downieville area, and this extends to the north of the fortieth parallel, into the area of the Honey Lake sheet. The basalt north of Red Clover Valley attains a thickness of over 1,000 feet, and is believed to have issued from vents in the vicinity. There are two areas southwest of Mount Ingalls along Little Grizzly Creek, two small masses on the backbone of the ridge east of the creek, and two small areas south of Long Valley Creek. There is a very small area of this lava by the Quincy road, 2 miles northeast of Bells Bar, another 1½ miles northwest, and still another 2 miles northwest of Bells Bar.

A large area forms the top of the ridge 1¾ miles north of Nelson Point, and there is a small mass at the head of Thompson Creek, and one forming the point known as Crescent Hill, 1½ miles southeast of Clermont Hill. Crossing to the south of the Middle Fork of the Feather River, we find it abundantly on the ridges north and south of Onion Valley Creek, and again west and south of Little Grass Valley. None of this peculiar lava has been noted in the south half of the Downieville area. It is probable that the older basalt issued at a number of vents, but the masses about Onion Valley Creek and the extensive sheets in the Bidwell area about Black Rock Creek, on the Mooreville ridge, etc., may perhaps have come from a single orifice near Onion Valley. At nearly all points the basalt is at the edge of areas of andesitic breccia, under which it usually extends. A complete analysis of No. 276 Plumas, from Red Clover Valley, is given in the table of the gabbro family in Chapter VI.

Doleritic basalt.—This is macroscopically a medium-grained, light-gray or pinkish rock, with often large, scattered olivines. Under the microscope it is seen to be often nearly or quite holocrystalline, and it usually contains much hypersthene. The largest area of this rock is that forming the upper two-thirds of Mount Ingalls, which appears to have been a source of eruption. There is still on the summit of the mountain some red, scoriaceous lava that may have formed part of the crater. It is thought that the eruptions of this late basalt took place in very early Pleistocene time, after the present drainage system had been initiated. It largely overlies andesitic breccia, and appears to have flowed down slopes that existed at the time of the basaltic eruptions. It occurs at numerous points in the large volcanic area north of Mohawk Valley, as at Big Hill, Penman Peak, and Mount Jackson. There is a large flow just southeast of Mohawk Valley, and another at Haskell Peak. There is a considerable mass of it on the summit of the ridge 2¼ miles southeast of Sierra City, and several areas on the ridge south of Downieville, one of which is known as Table Mountain. It also caps the andesitic ridge west of the head of Woodruff Creek, and is found at several points on the ridge between Fiddle and Canyon creeks. It forms the summit of Deadwood Peak southwest of Poker Flat and the summit of Clermont Hill. There are several masses on the north slope of Clermont Hill, an area (No. 64 Plumas) 4½ miles south of Tower Rock on the west slope of the Grizzly Mountains, one north of Bell's Bar, and one north of Long Valley. It is thus evident that this late doleritic basalt is scattered over nearly the entire Downieville area. It seems probable that the lava came out chiefly at the points at which it is now found. Except the scoriaceous material on the summit of Mount Ingalls, all the doleritic basalt is massive.

The basalt area of the point one-half mile south of the summit of Haskell Peak present the appearance of having flowed down over the rhyolite, which would presuppose the partial erosion of the rhyolite before the flow took place, and may be regarded as evidence tending to indicate a Pleistocene age for the basalt.

Analyses of the doleritic basalt.

	No. 314 Plumas.	No. 311 Plumas.	No. 196 Plumas.	No. 362 Plumas.
Silica	52.81	53.91	56.28	57.32
Lime	10.14	10.40	7.81	7.13
Magnesia	6.12	5.52	3.44	....
Potassa	1.05	1.34	1.38	1.39
Soda	2.75	2.90	3.38	4.14

The analyses of Nos. 311 and 314 are by Dr. Hillebrand. No. 362 by Messrs. Hillebrand and Steiger, and No. 196 by Mr. Steiger. Nos. 311 and 314 are from Mount Ingalls, No. 196 from Grizzly Peak, and No. 362 from the area 3½ miles northeast of Haskell Peak. No. 196 contains no olivine, but abundant hypersthene. It would be called a pyroxene-andesite by some petrographers, but the feldspars are chiefly labradorite, and in any case would belong to the labradorites of Fouqué and Michel-Lévy.

Late fine-grained basalt.—There are at several points small areas of massive, dark-colored basalts, usually showing olivine with the aid of a hand lens. These are provisionally grouped together, since they all appear to be later than the older basalt and differ from the doleritic basalt in structure and, to some extent, in mineral composition, although in some instances the two types appear to grade into each other. Many of the specimens with a resinous appearance resemble microscopically certain augite-andesites. The microscope shows that olivine in idiomorphic phenocrysts is universally present, as well as augite, in rounded grains and polysomatic groups. One sample (No. 202 Sierra Co.) shows also abundant minute hypersthenes.

The following areas are examples: A small mass about 1½ miles northeast of Goodyears Bar, on the east slope of the ridge and a little to the east of hypersthene-andesite area No. 209 S. N.; a dike with horizontal columns (No. 166 Plumas) on the ridge north of Cogswell Creek, in an area of the Auriferous gravels; a dike-like mass with horizontal columns (No. 170 Plumas), forming the point known as Lava Peak, and apparently later than the Neocene river gravels which lie about it; dikes (No. 666 S. N.) in the Auriferous gravels at Port Wine; the columnar mass 1½ miles south of Deadwood Peak; a considerable area, more than a mile long, about 1½ miles northeast of Rattlesnake Creek; the area just west of Whisky Diggings; the flow (No. 164 S. N.) west of Lincoln Valley; a mass (No. 842 S. N.) with slaty structure, forming the point, with an elevation of 7,532 feet, on the andesitic ridge 4½ miles east of the Sierra Buttes; a rounded mass on serpentine 1 mile west of Mount Fillmore. The last occurrence is partly columnar and partly has a brecciated appearance, weathering into mammillated forms. These lavas are presumed, like the doleritic basalts, to have issued at the points where they are now found. On the geologic map they are grouped with the doleritic basalts, being thought to be, partly, at least, of early Pleistocene age.

ANDESITE.

Hornblende pyroxene-andesite.—The Neocene volcanoes of the Downieville area threw out vast quantities of coarse lavas in which black needles of hornblende and augite crystals can usually be seen with the naked eye. In addition to the breccia, there are large areas of massive andesite of the same coarse type, some of which contain no hornblende. A few small areas of very acid andesites, usually containing biotite, are included with these coarser andesites on the geologic maps. For details concerning the distribution of some of the massive areas, the reader is referred to that part of the previous report relating to Grizzly Peak.[1] While these fragmental lavas are presumed to have been the result of explosions, and thus to have been scattered over the surrounding country, the rock over considerable areas appears to have been mixed with water and to have been veritable mud flows. Mr. Quigley, of Little Grass Valley, informed me that wherever in mining operations silicified trees were encountered in the cement lava (andesite tuff) they were lying at various angles, while in the gravel deposits they were found nearly horizontal. This would seem to indicate that the trees had become embedded in the detrital lava and been carried down with it. However, at two points definite fissures in the older rock are occupied to an unknown depth with the fragmental lavas, forming dike-like masses, so that at first glance one might suppose the lava came out at these points in a fragmental form. In the section on the Bidwell Bar area one of these dike-like masses has been described. Another similar occurrence is at Poker Flat. Here Canyon Creek has cut through the dike to a depth of 1,000 feet, and the tuff can be seen in place in the bed of the stream. Some years ago a shaft was sunk in this fragmental material, with the expectation of finding gravel under it, which was, needless to say, a hopeless task. The depth of this shaft is said to have been 100 feet or more, and nothing but the cement lava was encountered. The material may be seen to be distinctively stratified on the south bank of Canyon Creek just south of the Poker Flat Hotel, and in the bed of Grizzly Creek, which drains into Canyon Creek from the south. At other points, however, the material is a rubble of andesite-tuff and the wall rock (serpentine) of the dike. In addition, there were noted numerous fragments of a fine-grained white lava (No. 259 S. N.) in the tuff dike on the north bank of the creek west of Howland Flat road. These rounded fragments are composed chiefly of feldspar microlites in a glassy base. There are minute scattered shreds of biotite and opaque black prisms that may be an iron oxide replacing hornblende. According to A. Wedderburn, the rock contains 2.16 per cent of potassa and 3.48 per cent of soda. It appears to be a very acid lava of the type of dacites, in which the quartz occurs in the groundmass and not as porphyritic crystals. Rocks of this type were not found in place in the neighborhood. The Poker Flat fragmental dike may be supposed to be a fissure opened by an earthquake and filled in from above.

There is another mass of fragmental andesite in the bed of Canyon Creek 1½ miles farther up the stream, at a point where a large branch enters it from the north. Here a dike of rhyolite forms part of the bed of the creek and extends thence up the south side, as previously described. The andesitic mass is in contact and in part apparently overlies the rhyolite, of which it contains fragments. The andesite

[1] Fourteenth Ann. Rep. U. S. Geol. Survey, map opposite p. 486.

tuff (No. 635 S. N.) forms the bed of the creek for about 300 feet, and thence extends north for about 600 feet, but does not extend up to the ridge on either side, as at Poker Flat.

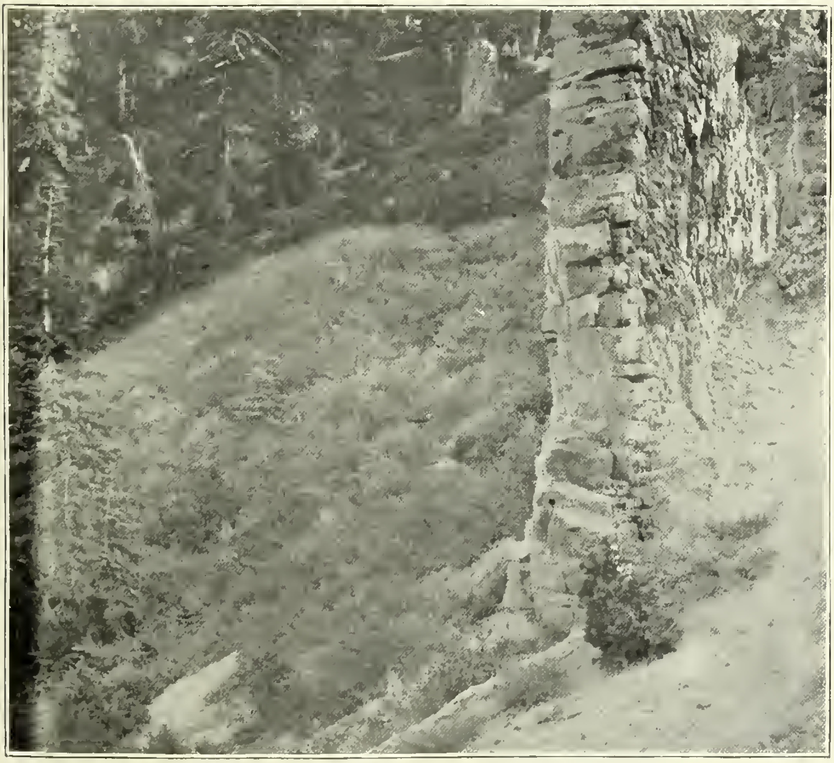
Prof. J. E. Clayton, in a report on the Plumas Eureka gold-quartz mine, which is on the east flank of the Eureka Peak, states that in one of the tunnels there was encountered "a dike of gray trachyte about 100 feet wide, identical in structure and appearance with the volcanic outflow in the neighborhood." The "gray trachyte" presumably refers to the andesite-breccia, an area of which caps the ridge just west of the peak.

The coarse andesite here described occurs as a massive lava on Blue Nose Ridge, at Pilot Peak, northeast of Onion Valley, on Mount Fillmore, west of Gold Lake (where it is columnar), on Fir Cap, and on Rattlesnake Peak Ridge. The massive andesite just east of Bassetts (No. 170 S. N.), at the mouth of Howard Creek, and 2 miles north of Bassetts (No. 248 S. N.), where it is columnar, is finer grained than much of the coarser type, but may be distinguished from the coarser portions of the fine-grained hypersthene-andesite, as the pyroxene is chiefly augite. No. 248 S. N. contains 1.74 per cent of potassa and 2.68 per cent of soda, according to A. Wedderburn. This fine-grained variety of the coarse andesite occurs also as a distinct dike cutting the clay slates in the bed of Canyon Creek 1 mile northeast of Poker Flat (No. 181 Sierra Co.). This dike extends up the south slope, gradually broadening, and forms a conical butte (No. 262 S. N.) 1 mile south of east from Poker Flat, where the lava in part lies in horizontal columns, and up the north slope, widening into an oval area 1¼ miles north of Poker Flat. There are also numerous small areas of a fine-grained massive hypersthene-andesite, hereafter to be described, but by far the greater number of the areas noted on the geologic map are made up of the coarse andesite tuff and breccia. Pl. XXVI, A, shows the unstratified character of this material in this area, although it is not meant to imply that no stratification is to be observed in the district. On the contrary, the material is occasionally distinctly arranged in layers, as on the east bank of the Middle Fork of the Feather River, northwest of Mohawk Valley.

There is a small patch of andesite tuff on the south slope of the Sierra Buttes at an altitude of about 7,000 feet, and as the tuff may be presumed to rest on a bit of the old Neocene surface, there is here evidence that Sierra Buttes formed a mountain mass in Neocene time, the present altitude being 8,615 feet, or 1,615 feet higher than the tuff.

There are granite bowlders on the backbone of a spur of Clermont Hill at about the 5,100-foot contour. This spur extends easterly from Limestone Point. Near its terminus, west of the road to Quincy and north of the Nelson Point bridge, there are also granite bowlders. Their position is anomalous, as the nearest area from which they could have been derived appears to be that at Happy Valley, 10 miles or more to the east. There is also a large granite bowlder on andesitic breccia on

A



B

A. ANDESITE-BRECCIA, SHOWING THE ENTIRE LACK OF STRATIFICATION
B. DIKE OF HYPERSTHENE-ANDESITE IN THE ANDESITE-BRECCIA.

the west slope of the Grizzly Mountains, on a spur 4 miles due east of Spring Garden ranch. Possibly at all these places the granite bowlders were formerly embedded in the andesite breccia, and were brought down with the volcanic material. This origin has already been suggested under Glaciers for the granite bowlders on the ridge 4 miles due west of the summit of Mount Ingalls.

Forming a flat-topped hill on the ridge 2 miles northwest of Downieville is a massive andesite (No. 626 S. N.) containing about 60 per cent of silica. The rock is remarkable as containing corroded quartzes which are surrounded by shells composed of augite-microlites, in this respect being like the quartzes of basalts described by Iddings and Diller.[1] There are also corroded feldspars in the rock and phenocrysts of a clear, nonpleochroic, rhombic mineral, probably enstatite. It is evident from the silica contents of the rock that it should not be called a dacite. Similar quartzes with the augite shells were noted in andesite No. 262, from near Poker Flat. No. 626 is likewise remarkable as containing a trace of chromic oxide, which may have been derived from the surrounding serpentine, through which it presumably passed in reaching the suface. (See complete analysis of this rock in the table of diorite family analyses in Chapter VI.)

Analyses of the coarse hornblendic andesites.

	No. 69 Plumas.	No. 72 S. N.	No. 262 S. N.	No. 198 Plumas.	No. 123 Plumas.	No. 626 S. N.	No. 16 S. N.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silica	57.32	58.47	59.34	59.97	60.00	60.02	60.20
Lime	7.13	6.60	6.45	6.09	6.33	7.01	6.04
Magnesia	....	2.69	3.50	....	....	4.57	2.69
Potassa	1.39	2.01	1.94	1.35	1.71	1.59	2.01
Soda	4.14	3.58	3.40	3.98	3.62	4.57	3.58

Analyses Nos. 72, 262, and 16 are by Dr. Hillebrand; Nos. 69, 123, and 198 by Messrs. Hillebrand and Steiger; and No. 626 by Dr. Stokes. No. 69 is from a large bowlder in the andesite breccia northeast of Laporte, and appeared to be a fair sample of the blocks in the breccia. No. 72 is from the andesite breccia at the southwest base of Mount Ingalls; No. 262 is from the columnar cone 1 mile southeast of Poker Flat, and is finer grained and probably later in age than the other andesites of the above table; No. 198 is a hornblende-mica-andesite resembling macroscopically the dacite of Lassen Peak, from $1\frac{1}{10}$ miles southeast of Grizzly Peak; No. 123 is from the large area $2\frac{1}{2}$ miles southwest of Eureka Peak; No. 626 is the quartz-bearing andesite previously noted northwest of Downieville, and No. 16 is a massive hornblende-andesite without pyroxene and with a cryptocrystalline groundmass, from 2 miles east of Mount Fillmore.

[1] Bulls. U. S. Geol. Survey Nos. 66 and 79.

Fine-grained hypersthene-andesite.—At many points in the large areas of andesitic material shown on the geologic maps are small bodies of a massive andesite that usually has a marked slaty fracture or laminated structure. The same rock forms also some isolated areas, and as it occurs in dikes in the fragmental andesite, it is evidently later than that material, and is therefore considered separately, although on the geologic map it is not distinguished by color from the coarser andesite just described. Pl. XXI, from an area of this rock on Franklin Hill in the Bidwell Bar district, gives a good idea of the laminated structure.

Macroscopically the rock is usually of light slate-gray color. Under the microscope it is characterized by a universal presence of hypersthene in minute laths, and in many cases the plagioclase occurs in the same form. Often there is no hornblende present, but about Poker Flat, Table Rock, and at some other points there are needles of brown hornblende, occasionally abundant. In some sections the plagioclase occurs in squarish phenocrysts in addition to the laths, but this is unusual. An analysis of 209 S. N. may be found in the table of analyses of the diorite family. It has a higher silica percentage than usual.

This rock forms isolated areas at the following localities: On the high points 1½ miles northeast (No. 209 S. N.) and 2 miles northwest (No. 153 Sierra Co.) of Goodyear's Bar; about one-fourth mile east of Denten's, in Mohawk Valley (No. 332 Plumas), a dike-like occurrence; and 1½ miles northwest of Saddle Back. It occurs in the same area with the coarse andesite at the following points: forming the top of a spur 1½ miles south of Sierra City; 2¼ miles northwest of Grizzly Peak; 1 mile north of Saddle Back (No. 258 S. N.); and forming the level-topped peak known as Table Rock (No. 263 S. N.) and the point 1¼ miles northwest of Table Rock. Dikes cut the fragmental andesite dike that crosses Canyon Creek at Poker Flat at several places southeast of that village. One of these (No. 630 S. N.) is shown in Pl. XXVI, B. Another dike (No. 631) in the andesite-breccia is on the backbone of the ridge 1½ miles southeast of Poker Flat. This dike is from 15 to 20 feet wide, with a north-and-south strike, and the lava is columnar.

On the west side of Illinois Canyon, about 1 mile east of south from Mount Fillmore, are numerous dikes of the fine-grained hypersthene-andesite in the detrital material which forms the base of the andesite-tuff. This fragmental material (No. 275 S. N.) is practically a continuation of the fragmental dike at Poker Flat, and contains numerous rounded fragments of the same fine-grained white andesite noted as occurring there, as well as fragments of vein quartz. The dikes in Illinois Canyon dip at angles of 50° to 60°, and are from 1 to 10 feet in thickness. There are also thin dikes of this andesite in the clay-slates by the road a little west of Downieville (No. 185 Sierra Co.).

THE SUBJACENT PRE-CRETACEOUS SERIES.

THE AURIFEROUS SLATE SERIES.

JURATRIAS BEDS.

Associated with the so-called quartz-porphyries of the Sierra Buttes ridge are certain lenses composed largely of siliceous argillite. These lenses are in part in the quartz-porphyry series and in part lie in its lower (west) border and upper (east) border. One of these areas, to the southwest of Gold Lake, is 2 miles in length, but usually the lenses are not so long. Certain thin layers, a fraction of an inch in thickness, in some of the argillite, weather white, contrasting strongly with the nearly black color of the remainder of the rock. At other points there are oval bodies about three-fourths of an inch in maximum diameter that might be easily mistaken for fossils. These have apparently the same composition as the remainder of the rock, and their origin is difficult to explain. Somewhat similarly shaped oval bodies occur in the Mariposa slates northwest of Bear Valley by the trail to Hell Hollow, and were supposed to represent casts of seeds, but these have been examined by Professor Ward, who is unable to indicate their nature. The finding of an ammonite in the argillite lens of the Phœnix mine was noted in the previous report.[1] This ammonite was loaned by Mr. Hendel and sent east for examination, but the writer has been unable to get any information about it. Mr. T. W. Stanton visited the locality at which the ammonite is said to have been collected, but was unable to find any traces of fossils. However, isolated specimens of ammonites have been found in the slates of the Sierra Nevada at other points, as reported by Whitney, and there is no good reason to doubt the find in question. This gives evidence of the Juratrias age of the argillite.

In another lens of sedimentary material, a portion of which is composed of the siliceous argillite and a portion of coarser sediments in part of volcanic origin, were found some radiolarian remains. The exact locality is on an east spur of the Sierra Buttes, about seven-tenths of a mile north of east from the main Sierra Butte. The vein of the Mountain mine is in this sedimentary lens, and the locality may be reached by the mine road which ends at this point. In a layer of fine breccia composed of small, light greenish-gray fragments cemented by fine sediment, nearly black in color, what appeared to be Radiolaria were noted in microscopic sections. These rounded bodies are in the black matrix and not in the gray fragments. The thin sections were referred to Mr. Charles Schuchert, of the National Museum, who reported as follows:

> The two slides contain forms much like the *Cenosphæra* and *Carposphæra* figured by Hinde, but are much larger than is usual for Radiolaria. I do not think that they will assist in determining the age of the beds in question. However, I have sent the slides to Dr. Hinde and asked him for his opinion.

[1] Fourteenth Ann. Rept., p. 449, and Am. Geologist, Vol. XIII, p. 232.

Mr. Schuchert kindly sent me Dr. Hinde's reply, a portion of which is herewith inserted:

I have duly received your esteemed letter of January 29, 1896, and the accompanying two slides of black chert with Radiolaria from the Sierra Buttes, Plumas County, Cal., which arrived a week later than the letter. I have carefully examined these chert sections and do not think that any conclusions as to the age of the rock can be arrived at from the character of the Radiolaria in them. In fact, both the chert and the organisms in it might just as well be Paleozoic as Mesozoic. I have ventured to make an exchange, and I am sending to you, under separate cover, a section of siliceous radiolarian rock from the lower Culm measures of Cornwall in place of one of your slides, so that you will be able to judge for yourself how similar in appearance Radiolaria may be from these widely distant localities. In the California rock the Radiolaria are somewhat smaller than the average of those in the lower Culm measures, but so far as I can make out the same genera are present as in the English peak, and where only the casts are shown a comparison of species is hopeless.

As outlined on the map, the Mountain mine area includes several distinctly volcanic beds. Beginning on the west, we have the following succession of the rocks:

1. No. 600, the quartz-porphyry of the Sierra Buttes area.
2. No. 601, a greenstone layer 200 feet thick, forming the summit of a little knoll.
3. No. 602, a dike or intrusive sheet of white quartz-porphyry 5 to 12 feet thick, and at one point plainly intrusive in 601.
4. Nos. 603 and 604, a plainly clastic series 150 feet thick.
5. A layer of quartz-porphyry (rhyolite-porphyry) or dacite-porphyry weathering a white color, having a thickness of about 50 feet. This may represent either an intruded sheet or contemporaneous flow.
6. No. 606. On the east border of the quartz-porphyry 605 is a black flinty layer about 3 feet in thickness. The microscope shows this also to be a quartz-porphyry.
7. No. 599. There is here a thin layer of greenstone tuff, and then a few feet of plainly stratified dark and light sediments (No. 588).
8. The quartz vein of the Mountain mine, about 10 feet in thickness.
9. No. 697. Above (east of) the quartz vein there is a crushed zone with more vein quartz, the thickness being perhaps 75 feet; then the fine-grained breccia (No. 607) containing the radiolarian remains. This breccia, with compact layers of siliceous argillite from 3 inches to 3 feet in thickness, and one conglomerate bed containing angular blocks of the siliceous argillite, continue down the road (east) for 500 feet, making the thickness of the layer 575 feet.

The clastic series of the Mountain mine may be said to end here, the entire thickness (Nos. 603–607 and 599) being approximately 700 feet.

10. Next east is No. 608. Quartz-porphyry tuff. The microscope shows this to be plainly clastic and to contain microlitic fragments, cryptocrystalline granular fragments (chert?), rounded volcanic quartzes, and fragmental feldspars. There are interbedded with this material a few thin layers of siliceous argillite.
11. No. 609. Also a quartz-porphyry tuff and lies just east of layer 608, the thickness of the two being perhaps 1,000 feet (approximate only).

The general strike of the clastic beds of the Mountain mine and the quartz-porphyry tuffs lying just east is to the west of north, and the dip, except in the crushed zone along the quartz vein, is uniformly to the east at from 50° to 60°.

Overlying the above beds are more even-grained greenstone tuffs (Nos. 610 to 612), which may be called uralite-andesite tuffs, the original

JURATRIAS VOLCANIC BRECCIA, SHOWING SYSTEM OF FISSURES OR JOINT (?) PLANES.

augite being largely replaced by uralite, etc. This is plainly a more basic series and does not, so far as examined, contain original free quartz. Although these massive tuffs exhibit planes or partings parallel to the dip planes of the underlying sediments, no clear evidence of the dip of these beds was noted along the Mountain mine road, where they are finely exposed. The uralite-andesite tuff bed continues eastward (down the slope) for more than 3,000 feet, where the underlying rock is obscured by morainal material. However, about 1 mile farther south, in the bed of the North Fork of the North Fork of the Yuba River, this uralitic augite-feldspar tuff is plainly seen to be overlain by the red slates and fine-grained tuffs of the Milton formation. The same succession of the beds here indicated, from the quartz-porphyry to the Milton series, inclusive, is also to be seen on the south side of the canyon of the South Fork of the North Fork of the Yuba to the east of Sierra City.

The Juratrias beds, showing beyond question the original stratification, have been farther north much compressed, and when first seen in the region about the Salmon Lakes and Gold Lake, where the tuffs may have been largely deposited subaerially, no evidences of an original bedding were detected. After having seen the beds at Milton and on the east slope of the Sierra Buttes, the lake region was again visited. Four miles west of north from the Mountain mine sedimentary area, to the east and northeast of Deer Lake, another lens was found, composed of siliceous argillite and tuff beds, dipping 35° at one point, but at other points the dip was much higher. The area here referred to is shown on the geologic map. On account of the flat dip and the erosion the country has undergone the siliceous argillite layers can not be traced continuously. Probably one examining the area as marked out would conclude at first that it should not be represented as a sedimentary mass, since the porphyry-tuff is the most noticeable part of it, and it is only by careful search that the evidence of the interbedding of these tuff masses with layers of the black siliceous argillite can be discovered.

In the neighborhood of the Salmon Lakes the dip of the tuffs is much obscured. At various points, however, lines of partings, with layers of different color and texture, may be regarded as evidence of the original bedding. A good place to see this is at the outlet of Upper Salmon Lake. The dip of these beds is about the same as that of the clastic area northeast of Deer Lake, being 40° to 45° to the east. A secondary structure or fissure system is, however, much more noticeable than the obscure lines of original bedding. This fissure system is illustrated by Pl. XXVII, which is from a photograph of a porphyry-tuff bed one-half mile west of Upper Salmon Lake. There is no evidence of the original bedding at this point. The partings are nearly vertical and strike east and west magnetic (var. 17° E.).

The areas on the geologic map to the east and south of Mohawk

Valley shown as of Juratrias age may belong to another series. However, the tuffs of the area by the Middle Fork of the Feather, one-half mile upstream from the mouth of Willow Creek, are plainly bedded and appear to have been laid down in water. They strike north and south and dip 68° to the east, and much resemble the tuffs of the Milton formation. The area forming a hilltop 2½ miles due east of Dentens is composed in part of a wollastonite (?) schist, like a portion of the area just northeast of the Sulphur Spring House. In the latter area also are some tuffs and garnet rock. Indeed, in all of these small areas the amount of igneous material is large, and further investigation will be necessary before the age of these areas will be known. The same may be said of at least a portion of the sedimentary material on the slope of the ridge west of the Antelope House. If the writer is correct in regarding the district to the east of Mohawk Valley as a downthrown area, these so-called Juratrias beds on the east of the valley may easily have been directly connected before the faulting occurred with the supposed Juratrias area extending from Howard Creek north to near Mohawk Valley.

It is probable that the Juratrias beds above described are nearly related to the Sailor Canyon series of the southeastern part of the Colfax district.

MILTON FORMATION.

In the neighborhood of the old stage station known as Milton, on the Middle Yuba, there are exposed a series of beds, largely tuffs, all of which, from their evenly bedded arrangement, present the appearance of having been laid down under water. These beds contain much pyroclastic material of the augite-andesite type, some quartzite, fine-grained red slates, a little limestone, and a variegated breccia or conglomerate, a bed of the latter being found by the road at Milton. This breccia contains abundant small fragments of chert and other rocks of various colors, and as was noted in the previous report, appears to have furnished the variegated pebbles referred to in the description of the Neocene river gravels of the Bidwell Bar and Downieville areas. Limestone, or more accurately marble, was seen at two points only, one 1.6 miles northeast, and the other 2.4 miles southeast of Milton, at both places close to the contact with the large granitic mass of the southeast corner of the Downieville area.

The limestone contains yellow and reddish garnets and a wollastonite-like mineral, presumably as a result of contact metamorphism. There is, therefore, little doubt that the adjacent granitoid mass is later in age than the Milton formation. At the marble locality, 2.4 miles southeast of Milton, just at the contact, the granite rises as a steep wall above the level of the Milton sediments and the bedded rock appears to abut directly against the granite wall, the dip being easterly, that is, toward the granite. The hardened sandstone or quartzite of the series contains a good deal of an anthigenic brownish-green mica

GENTLY DIPPING BEDS OF THE MILTON FORMATION, SHOWING SYSTEM OF FRACTURES CUTTING THE BEDDING PLANES.

in minute foils, which may likewise be ascribed to metamorphism. However, this body of sediments as a whole shows like evidence, both macroscopically and microscopically, of having been greatly compressed. Not only has very little secondary schistosity been developed, but under the microscope the grains usually show little evidence of crushing. The dip in the neighborhood of Milton is quite uniform to the east at 40° to 50°, with occasional dips as low as 25°. At the granite contact it is in places much steeper. The Milton series seems to rest unconformably on the presumably Paleozoic sediments that form the mass of the range in the Downieville area west of Milton. These Paleozoic (?) rocks consist of black slates, quartzite, and magnesian limestone. They stand approximately vertical and are much compressed. The difference in the lithologic character of the two sets of rocks, the fact that one shows much evidence of dynamic metamorphism and the other comparatively little, and the marked difference in dip of the bodies taken as a whole, strongly suggest an unconformity. In the Milton series the original planes of stratification form one of the most noticeable features; in the magnesian limestone series the schistosity is more prominent and the original bedding made out with difficulty.

A few dikes of diorite (No. 232 S. N.) and of diabase-porphyry (No. 45 S. N.) cut the Milton rocks, and a large lens-shaped area of diabase-porphyry (No. 246 S. N.) lies just west of a strip of sedimentary rock on Howard Creek, presumed to belong to the Milton series.

Although, as above stated, there is usually little difficulty in recognizing at a glance the bedding planes of the Milton formation, the strata are at some points intersected by a system of fissures which cut across the bedding planes.

Pl. XXVIII illustrates this. The beds shown in the plate dip east at an angle of about 25°, the fissure planes dipping west about 60°. The picture was taken looking south. As may be seen in the illustration, there are a set of light-colored lines lying approximately parallel to the fissure planes. They are, in fact, partings filled with secondary products (epidote, etc.), such as may be seen along the true bedding planes at other points in the Milton tuffs. If the true bedding were not here apparent this secondary structure might easily be mistaken for original bedding. The water-laid tuffs and sediments of the Milton formation extend southeast and form a considerable area in the northeast portion of the Colfax district.

The relation of the Milton series to the quartz-porphyry of the Sierra Buttes ridge and the associated argillite lenses is made clear by an examination of the spur of the buttes on which the Mountain mine is located, as described above. It is distinctly later in age than these supposed Juratrias rocks, and are probably of Jurassic age, for the collective evidence is good that there are no Cretaceous rocks represented in the older complex (Auriferous slate series and associated igneous rocks) of the Sierra Nevada.

ROBINSON FORMATION.

Under this head are grouped some metamorphic tuffs and ordinary sediments, which form several areas in the northeastern portion of the Downieville area. A considerable number of fossils from a locality on the west side of Little Grizzly Creek were examined and reported on by Mr. Charles Schuchert, and this report was printed in the preceding paper[1] under the head of "Little Grizzly Creek beds." As there can be little doubt of their being of the same age as Mr. Diller's Robinson beds in Mount Jura, on the north side of Genesee Valley, they will be correlated with them and called the Robinson formation. A new locality of fossils in this formation was discovered by Mr. T. W. Stanton. It lies just to the north of the fortieth parallel and in the area of the Honey Lake sheet. The fossils were found in a bluish-gray calcareous slate (No. 78 S. N.). One of these (Phillipsia) is a trilobite, so that to Mr. Stanton belongs the credit of being the first to discover one of these interesting crustaceans in the Sierra Nevada. These also were referred to Mr. Schuchert, who reported as follows:

Locality.—Trail from Little Grizzly Creek to Genesee Valley, Plumas County, Cal., about 3 miles northeast from Tower Peak, on the slope west of Ward Creek, near the top of the ridge.

Faunal list.

Orthis michelini L'Éveille.

Has been identified a number of times in the American Lower and Upper Carboniferous.

Streptorhynchus crenistrius of American authors.

The poor condition of these specimens does not allow me to make out their generic characters and therefore also not their specific. They represent a species of either Derbga, Orthothetes or Streptorhynchus.

Ambocœlia planoconvexa Shumard sp.

This species in America is restricted to the Upper Carboniferous.

Spirifer striatus Martin sp.

Has been identified a number of times before in the American Carboniferous.

Productus?

Two poorly preserved species.

Pelecypod like Goldia or Leda.

Phillipsia sp. undet.

The cephalic portion is not well preserved and does not enable one to make out the species at this time.

Lophophyllum proliferum McChesney?

These specimens are smaller than usual for the species.

Crinoid column segments.

The Robinson formation is considered by Mr. Walcott and Mr. Schuchert as of Upper Carboniferous age, and is thus distinguished from the Calaveras formation, which is lower in the Carboniferous and may include older Paleozoic beds.

Prof. J. P. Smith[2] gives a list of fossils collected by H. W. Fairbanks on the McCloud River, which he thinks the equivalent of the Robinson

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 448.
[2] Jour. of Geology, Vol. II, pp. 601-602.

formation, although he places them in the Pitt formation of Mr. Fairbanks, described later, which includes some Triassic beds. Professor Smith agrees with Mr. Walcott and Mr. Schuchert in regarding the Robinson formation as Upper Carboniferous. In the Downieville area a characteristic feature of the formation is a tuff in which porphyritic feldspars are usually to be seen. Chemical analyses appear to show these tuffs to have the composition of trachytes, and this is confirmed by a microscopical examination, for while the feldspathic material of the groundmass is difficult of determination on account of the minute size of the grains and the presence of much secondary mica, the porphyritic feldspars are seen to be microcline and orthoclase in the specimens analyzed from the Downieville area (Nos. 219 and 352 Plumas). In No. 80 S. N., collected by Mr. T. W. Stanton from the original locality of the Robinson formation, north of Genesee Valley, the groundmass appears to have been very glassy, but to now be devitrified. Such a rock may be called an apo-trachyte. However, this devitrification yet remains to be demonstrated. The phenocrysts in No. 80 are not all a potash feldspar, some being twinned on the albite law.

Analyses of the tuffs of the Robinson formation.

	No. 80 S. N. *a*	No. 352 Plumas. *b*	No. 219 Plumas. *b*
	Per cent	*Per cent.*	*Per cent.*
Silica	....	55.29	53.98
Magnesia	....	1.31	....
Lime	....	3.08	2.78
Potassa	5.01	5.58	4.88
Soda	1.94	4.65	5.03

a Wedderburn, analyst. *b* Steiger, analyst.

South of Little Grizzly Creek there are two areas of metamorphic tuffs represented on the geologic map as belonging to the Robinson formation. This reference is made on a lithologic basis, as no fossils were found in these areas. No. 352 came from the area southwest of the Otis ranch. As may be seen above, this has the same composition as No. 219, which is from the Little Grizzly Creek fossil locality. The microscope also shows that both of these rocks have the same structure and composition.

Three and two-tenths miles southwest of Mount Ingalls there are fragments of the Robinson tuff in the granite, and at the same place a narrow finger of the tuff extends south into the granite, as shown on the geologic map. Farther away from the contact, a little to the south of the above point, a fragment of the tuff having a length of perhaps 8 inches was found in the granite. The microscope shows that the material of the inclusion has undergone a complete recrystallization, and is now practically a pyroxene-gneiss as far as microscopic structure and composition go. Surrounding this nodule (No. 77 S. N.) is a rim of macroscopically black hornblende about three tenths of an inch in thickness, the prisms of which stand normal to the surface of the nodule. The line of contact of the hornblende rim with the included fragment and with the surrounding granite is sharp. Fig. A, on Pl. XXIX, is from a photograph of this specimen. The hornblende rim seems to represent a basic segregation from the quartz-diorite magma. It will be noted that the rim has been fractured at one point and recemented by the quartz-diorite material, and that a black layer (hornblende) has formed in the lighter-colored quartz-diorite material parallel to the inner hornblende rim.

Another thoroughly recrystallized specimen from the tuff finger referred to above is made of lath-like plagioclase with undulous extinction and green hornblende. The edges of the grains of hornblende and of the feldspar laths are irregular.

At the east edge of the map may be noted two areas colored as belonging to the Carboniferous. One of these is to the north and the other to the south of Grizzly Valley. These rocks are thoroughly recrystallized and look more like gneisses than sediments. Another hornblende-gneiss that may be a contact form of a sediment or tuff forms a small lens in the granite 4 miles south of east from Milton. Although these areas are placed in the Carboniferous, they may be older, or if their gneissoid condition be regarded as the result of contact metamorphism, they may even be younger.

In the Little Grizzly Creek area, at different points, were collected curious orbicular structures (Nos. 896 and 1681 S. N.), the origin and structure of which remain to be investigated. In fact, the area above referred to contains a great variety of rocks, at least as judged from their macroscopical appearance, and well deserves a special study.

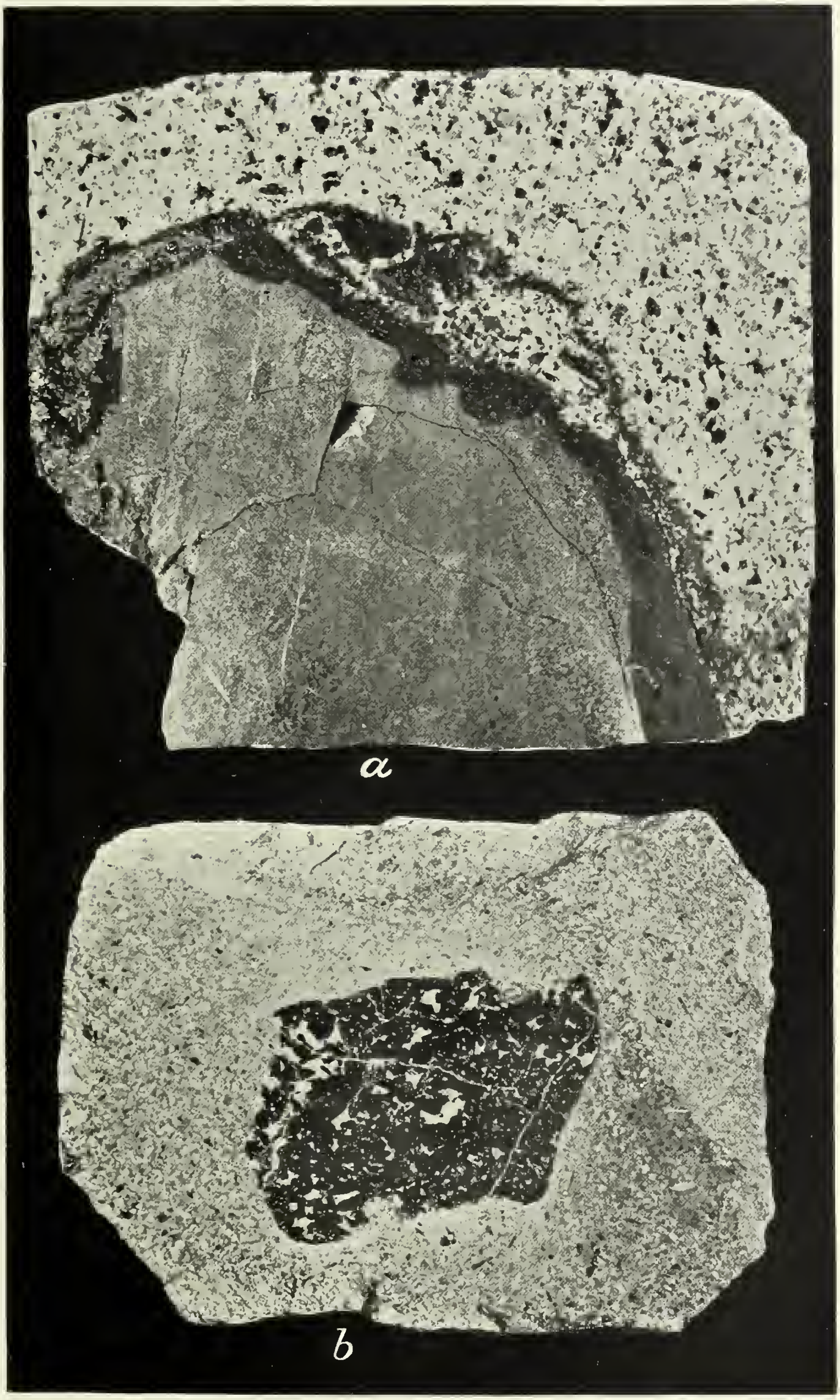
In the same area of the Robinson formation just referred to, a little to the south of the fortieth parallel, there are layers of red slate a few feet in thickness interbedded with a light-gray volcanic tuff, containing numerous small feldspar phenocrysts which weather white. The tuff layers contrast very noticeably with the red slate. The strike of the series is 13° west of north and the dip is 60° E. The groundmass of the tuff (No. 63 S. N.) shows traces of a flow structure in the arrangement of the particles. Whether or not this lava has the composition of a trachyte was not determined.

CALAVERAS FORMATION.

No evidence of the age of the Calaveras formation has been obtained beyond that given in the preceding report.[1] However, Professor Smith, in his paper on the metamorphic series of Shasta County,[2] finds that the McCloud limestone, which is regarded by the writer as part of the

[1] See also Am. Geologist, Vol. XIII, p. 229.

[2] Jour. of Geology, Vol. II, pp. 599–601.



a. NODULE IN QARTZ-MICA-DIORITE, SURROUNDED BY A RIM OF BLACK HORNBLENDE.
b. HORNBLENDIC INCLUSION IN HORNBLENDE-LABRADORITE-PORPHYRY DIKE.

Calaveras formation, is in part Upper Carboniferous. After giving the list of fossils determined by Meek from Bass ranch, Professor Smith writes as follows:

> Taken by itself the fauna would not be characteristic of Upper Carboniferous, and indeed it is arbitrary to draw the line at the base of the limestone. Even *Fusulina cylindrica*, which in the region east of the Rocky Mountains seems to be characteristic of Upper Carboniferous, in Nevada is found also in Lower Carboniferous. But the most decisive proof of the Upper Carboniferous age of these strata is their position so far above the Baird shales, which have been shown in this paper to be equivalent to the Lower Carboniferous of the Eureka district, Nevada, which is known to occur 3,000 feet above the base of the formation.
>
> The McCloud limestone is probably equivalent to the limestone of the Caribou formation of Plumas County. But J. S. Diller thinks that they belong to a lower horizon than that assigned by the writer. The Robinson beds of the Taylorville section are probably higher up in the section, but nevertheless the McCloud limestone is, in part at least, equivalent to the Coal Measures.

The "Caribou formation," referred to by Professor Smith, was so named in a preliminary edition of the Lassen Peak folio. The term has since been withdrawn by Mr. Diller, and does not appear in the final Lassen Peak folio.[1] The "Caribou formation" of this preliminary edition is the Calaveras formation of the final edition, the latter name having priority and covering the same ground.

As used in the Gold Belt sheets, the Calaveras formation includes all of the Auriferous slate series older than the Juratrias and Upper Carboniferous beds, known as the Robinson formation. As fast as definite horizons are recognized within the Calaveras formation they will be separated and designated under other names, so that if finally the age of all the contained horizons is ascertained there will be no longer any use for the term.

There can be no doubt that in northern California the Auriferous slate series is much less altered than in the Sierra Nevada, and is, moreover, much more fossiliferous, so that the composition of this complex, and consequently a scientific division into formations, can be made out much better there than in the Gold Belt region, where fossils when found are in nearly all cases crushed and distorted.

As may be seen by inspecting the geologic map, there are numerous areas of limestone in the eastern part of the large tract mapped as Calaveras. This limestone weathers in very rough shapes and is usually a dirty light-gray color, and in this respect is distinguishable from the dark bluish-gray limestone which has thus far furnished the fossils of the Calaveras formation. At the writer's request Mr. T. W. Stanton examined a large number of these croppings for fossils, but found nothing whatever that could be determined as organic. There being no known unconformity between these beds and those known to contain Calaveras formation fossils, they are called on the map that formation.

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[1] Geologic Atlas of the United States, Lassen Peak folio (No. 15), 1895

Chemical analyses were made by Mr. Steiger of two specimens of this light-colored limestone, and are herewith appended. They are very distinctly magnesian limestones.

Analyses of magnesian limestones.

	No. 86 S. N.	No. 153 S. N.
	Per cent.	*Per cent.*
Silica	2.29	4.90
Iron oxide	....	.36
Lime	30.19	31.33
Magnesia	9.99	19.61

No. 86 is from the large mass known as Limestone Point, on a southeast spur of Clermont Hill.

No. 153 is from a lens north of Loganville, and was collected by T. W. Stanton.

The magnesian limestone series contains more or less material of volcanic origin, now so much compressed and altered that it is difficult to say exactly what was its original nature. Some of the igneous masses have been separated from the clearly clastic material, as on the southwest slope of the Sierra Buttes, but this was impracticable at other points, since the interbedded volcanic material formed no definite areas that could be determined. An excellent place to see this complex of rocks is on the north slope of the main ridge, about 1¼ miles southwest of Bunker Hill. Here the rocks have been cleaned off by the former glacier that occupied the basin. Specimens 125 to 128 S. N. were taken within a horizontal distance of about 600 feet, and, so far as could be determined in the field, were parts of one uniform rock mass, there being no indication that any one was intrusive in any other. As determined by the microscope, No. 125 is a uralite-diorite, the plagioclase feldspars being much broken and bent. It was without doubt a thoroughly granular rock, and may represent an intrusive mass. No. 126 is composed chiefly of a very minute network of uralite fibers, with veins of secondary quartz. No. 127 is a tuffaceous sandstone, the clastic nature of the quartzes and feldspars being evident. There is some uralite present. No. 128 was doubtless originally a holocrystalline plagioclase-pyroxene rock, perhaps a diabase, but the feldspar is now thoroughly altered, and uralite is very abundant in rather large grains that are much sheared and drawn out in one direction. The rock has evidently been subjected to great pressure. The series 125 to 128 represents a unit in so far as the rocks composing it have been subjected to the same dynamo-metamorphic agencies which have formed schists of the entire series and pretty thoroughly masked the original nature of the components.

Cutting this series is a large dike of quartz porphyry (No. 129 S. N.)

about 30 feet thick. This extends down the cliff toward about N. 30° W.

Cutting the quartz-porphyry in a nearly east-west direction is a dike of a granulite-like rock (No. 130 S. N.) composed of a plagioclase feldspar resembling albite, and of muscovite, with epidote and chlorite present as secondary products. Quartz appears to be present, but the feldspar much resembles quartz when not twinned.

Just east of the 128 to 130 series is a strip composed of serpentine and of chlorite and talc schists, and to the east of this the rocks of the magnesian limestone series are more plainly sedimentary, being composed of fine-grained quartzite (No. 136), hardened sandstone (No. 135), and some limestone. To the west of the little lake that lies in the glacial basin southwest of Bunker Hill the quartzite dips in varying directions and the amount of igneous material appears to be less than on the slope to the south of the lake.

On the southwest side of the lake are fine exposures of the thin-bedded quartzite, it being here folded and contorted much as are the radiolarian cherts of Lawson's Franciscan[1] series in the Coast Ranges. Associated with the quartzite are some layers of iron ore (No. 147 Plumas), the croppings of which are very irregular, as if deposited with the quartzite and afterward folded with it.

By far the larger part of the Calaveras rocks in the Downieville area are clay-slates. About American Valley, along Nelson Creek, and to the east of Downieville, these do not appear greatly altered. Nevertheless, characteristic fossils were not found in them. On Clermont Hill the slates are very siliceous. They appear, indeed, to be infiltrated with secondary silica.

Along and to the east of the serpentine and amphibolite belt that extends from Oak ranch to Goodyears Bar there is a coarse quartz rock, which, under the microscope, is seen to be greatly crushed, the quartzes showing undulous extinction in a very marked manner. No. 198 S. N. shows, in addition to the greatly crushed and sheared quartzes, little garnets and radiating brushes of fibers in the quartzes. The nature of the fibers was not determined. This quartzite-like rock is greatly contorted in places, and in general the dip and strike are variable. These rocks are put in the Calaveras formation, although it is not clear that they certainly represent a sedimentary mass. It may, indeed, be a highly altered gabbro (see specimens 198, 210, 212, and 213) in which the original feldspar and pyroxene have been replaced by quartz.

On the ridge south of Fiddle Creek and in the canyon of the Middle Fork of the Yuba, east of Indian Valley, the slates are so filled with dikes of various kinds and augitic tuffs that some portions of this area contain as much (or more) igneous as sedimentary material. The irregularity of the dikes and the small size of any single dike make it

[1] Fifteenth Ann. Rept. U. S. Geol. Survey, p. 420. The outcrop here represented shows no contorted layers.

impracticable to represent them on the geologic map,[1] and the augitic tuffs are in thin masses in the slates. On this ridge were collected fine-grained argillite and cherts, in some of which traces of altered chiastolite are to be seen.

The slates colored as the Calaveras formation west of Scales are in part greenish and contain some secondary hornblende. They appear to have been deposited under water, as they show the bedding planes to perfection in places, for example, by the road directly west of Scales. This sort of material forms the ridge to the west of the Poverty Hill gravel area. Some of it might be mapped as greenstone-schist, but taken as a whole it is believed to represent a truly sedimentary mass containing a variable amount of volcanic material and is probably very similar to the Milton series, portions of which contain more pyroclastic material than ordinary sediments.

The same greenstone tuffs that were noted on the ridge south of Fiddle Creek are represented in the Calaveras formation along the Yuba River east of Indian Valley by layers at many points. but the individual layers are too narrow to be shown on the map. One mass near the granite area has undergone an incomplete recrystallization, presumably as a result of contact metamorphism.

The areas of sedimentary rocks of the Grizzly Mountains, colored on the geologic map as belonging to the Calaveras formation, comprise in part much altered rocks, and contain, particularly in the drainage of Long Valley and Cogswell creeks, much igneous material. The narrow area to the west of the quartz-porphyry belt is in part a siliceous argillite, which may be assigned to the Silurian on certain grounds and to the Juratrias on other grounds, as explained in the paragraph on quartz-porphyry.

THE UNALTERED IGNEOUS ROCKS.

GRANITE.

In the southwest corner of the Downieville district. forming a small area having a maximum diameter of about 2 miles, is a coarse-grained granitic rock which approximates in composition a true granite. In general it is characterized by the abundance of biotite and the lack of hornblende, although one of the specimens from the west edge of the area shows a mere trace of biotite and rather numerous small, irregularly developed prisms of green hornblende. The locality is a very interesting one, on account of the great abundance and variety of dikes that cut the surrounding rocks. Indian Valley, on the North Yuba, has been carved out of this granite. which extends up the ridge to the south. forming the east part of the eminence known as Indian Hill. The dike rocks will be described under other headings. Most abundant are quartz-diorite-porphyries, which cut the Indian Valley granite itself

[1] A few may be represented in a diagrammatic manner.

(see No. 304), and the surrounding rocks as well. One pyroxene syenite dike was noted. There are also porphyritic dike-rocks, belonging to the diorite family, more basic than quartz-diorite porphyries. These appear to be the latest of the dike rocks at this as at other localities in the Sierra Nevada.

On the south, and on the east and west as far north as the river, the granite is bordered by serpentine, which is derived from peridotite, in some of which olivine is still to be noted (No. 307 S. N.). A very pretty study could here be made of the composition, relative age, and genetic connection of the different igneous rocks represented. At present these relations can only be suggested. The following order of succession may be indicated as the probable one:

1. The clay-slates and associated greenstones. The slates are probably of Paleozoic age and the greenstones are chiefly augitic and uralitic tuffs interbedded with them.
2. Peridotite and serpentine derived therefrom.
3. Granite of Indian Valley.
4. Dikes of granite-porphyry (No. 306 S. N.), of quartz-diorite-porphyry (Nos. 304, 290, 292, and 584 S. N.), and pyroxene-syenite-porphyry (No. 281 S. N.).
5. Diorite dikes, sometimes with a nearly panidiomorphic structure.

The following description of the granite of Indian Valley represents fairly well the average rock. A complete analysis of this is given in the table of analyses of rocks of the granite family, in Chapter VI.

Biotite-granite (No. 303 S. N.).

Locality: North bank of the North Yuba, near the east border of the Indian Valley granite area.

Macroscopically, a coarse-grained, light-gray, granitic rock with abundant biotite.

Microscopically, the structure is hypidiomorphic or granitic. The rock is composed of plagioclase with idiomorphic tendency, unstriated feldspar in part orthoclase, rather small grains of interstitial quartz, brown mica in rather large plates, and a little apatite and iron oxide. Two of the plagioclases, twinned on the Carlsbad and albite laws and cut normal to the twinning plane (010), were determined to be andesine.

No. 306 is from a dike-like mass in the serpentine on the south slope of Indian Hill in the bed-rock of the hydraulic gravel mine. It may be an apophysis of the Indian Valley granite area, the edge of which is close by. The rock has a porphyritic tendency, there being traces of a microcrystalline quartz-feldspar groundmass between some of the larger anhedrons.

Analyses of the Indian Valley granite.

	No. 303 S. N. *a*	No. 306 S. N. *b*
	Per cent.	*Per cent.*
Silica	68.65	....
Lime	3.07	....
Potassa	1.85	3.86
Soda	4.85	3.42

a Hillebrand, analyst. *b* Wedderburn, analyst.

One and a half miles northeast of Rattlesnake Peak is a small area of a light-colored rock (No. 255 S. N.) which the microscope shows to be a micropegmatite. It is classed with the granites, although the character of the feldspar of the micropegmatite was not determined. Plagioclase is present, but is in part altered. Usually it is surrounded by micropegmatite. The ferromagnesian constituents have been altered to chlorite and epidote.

GRANITE-PORPHYRY.

Porphyritic rocks having the composition of granite have been found only as dikes in this area.

No. 581 is from the ridge extending east from Indian Hill, and it represents the dike-like protrusions of an area shown on the Colfax geologic map.

No. 124 is from a dike in the bed of the east branch of Nelson Creek. The groundmass of this rock is nearly cryptocrystalline. Mr. A. Wedderburn found No. 124 to contain 1.95 per cent of potassa and 5.30 per cent of soda.

No. 203 is a dike along a large quartz vein by the trail about one-half mile south of the St. Charles ranch.

In the bed of Onion Valley Creek, near the west border of the Downieville sheet area, dikes of granite-porphyry (Nos. 90 and 92 S. N.) from 4 to 8 feet wide were found by Mr. T. W. Stanton and myself cutting the black argillaceous schists of the Calaveras formation. Nearly all the granite-porphyries of which thin sections have been examined contain muscovite.

GRANULITE OR APLITE.

Under this head are placed certain white granites in which dark constituents form a small part of the rock or may be altogether wanting. Typical granulites or aplites are abundant as dikes cutting the quartz-mica-diorite of the eastern portion of the area. They are composed usually of quartz, orthoclase, or microcline, with a little plagioclase and sometimes biotite. No. 161 is from a dike in the quartz-mica-diorite by the road to Sierra Valley. Another similar granulite (No. 227) from the east of Milton is also a dike in quartz-mica-diorite. Complete analyses of both of these will be found in the table of analyses of the granite family in the chapter on rock classification. Dikes of potash granulites also cut the granite of Indian Valley.

The same soda-granulites noted under the Bidwell Bar area as cutting the serpentine of Grizzly Hill and about Meadow Valley are found in the Downieville area on the west flank of Clermont Hill. What appears to be a dike of this nature, but very coarse grained (No. 97 S. N.), was collected in the amphibolite-schist area east of Little Grass Valley.

Analyses of granulites.

	No. 227 S. N. (a)	No. 161 S. N. (a)
	Per cent.	*Per cent.*
Silica	75.97	76.03
Lime	1.49	1.28
Potassa	5.62	5.18
Soda	2.51	2.98

a Hillebrand, analyst.

On the ridge 5 miles southeast of Downieville is a considerable area of granitoid rock having a maximum width of nearly 3 miles and a much greater length, as it extends south into the area of the Colfax sheet. This rock is characterized in general by an abundance of quartz in large grains, sometimes one-half inch in diameter, and the lack of ferromagnesian silicates. In the northwest corner of the area, and to a certain extent at other points, however, the last elements are well represented in the rock. In the sections examined the feldspars are too decomposed for determination. There are numerous quartz veins in this granitoid rock, and in Harris Meadows abundant green dikes were noted (No. 216 S. N.). These dikes will be further referred to under the head of ophitoid quartz-augite-diorite.

About 4 miles east of Downieville, in the canyon of the North Yuba, is a small area of granitoid rock similar to the Harris Meadows area on the ridge to the south. No certainly original ferromagnesian silicates were detected in the section examined (No. 624 S. N.). The quartz has an idiomorphic tendency, and much of the feldspar is twinned on the albite law, with a maximum symmetrical extinction angle on 010 of 16°, so far as measured. According to Dr. Fireman, of the Columbian University, this rock contains but .3 per cent of lime, and the feldspar is therefore albite. The rock may be called a soda-granulite.

PYROXENE-SYENITE.

Just west of the granite of the Indian Valley area is a body of mixed rocks, in considerable part of the magnesian series (serpentine, tremolite, and talc-schists), but containing streaks of clay-slates and dioritic rocks. One mass (No. 285 S. N.) contains much colorless monoclinic pyroxene, showing in the larger anhedrons, which are of irregular shape, the prismatic cleavage, on which extinction angles were measured in eight cases, varying from 27° to 43°, the average being 33°. Much of the pyroxene is in small grains. Gray grains, in part feldspar with presumably some quartz, form with the smaller pyroxene grains a mosaic-like groundmass in which the large pyroxenes are embedded. The nature of this pyroxene rock is not known. In it was collected a white dike with porphyritic biotites (No. 284 S. N.), which at the time was supposed to be a quartz-diorite-porphyry, dikes of which are very abundant about Indian Valley. There are also at the same locality, in the same magnesian series here referred to (No. 280–282), abundant other dikes, from 2 to 40 feet thick, which, in the field, were supposed to be quartz-diorite-porphyry, but as no specimens were collected their nature remains to be determined. Cutting both the magnesian series and one of the dikes last mentioned is a diorite-porphyry (No. 283), a sample of which was collected.

The dike No. 284 above referred to proves on microscopic examination to be a syenite-porphyry composed chiefly of a turbid alkali feldspar, in interlocking grains forming a groundmass in which are embedded larger irregularly-shaped anhedrons of similar feldspar and of a green monoclinic pyroxene. This turbid feldspar appears in part to be orthoclase, but the amount of soda present, as determined by a partial chemical analysis,[1] suggests anorthoclase. A little albite-twinned feldspar is also present. Rather abundant is a somewhat pleochroic titanite-like mineral in irregular grains, and there is also apatite. Biotite and a garnet-like mineral were noted macroscopically in the rock, which is strikingly similar to a dike collected in the Sonora area (No. 950 S. N.).

In two publications[2] the writer has referred a rock (No. 165 S. N.) forming a considerable mass in the southeast part of the Downieville area to the augite-syenite group, but further investigations indicate that it is more nearly related to the pyroxene-diorites. It is treated of in this paper under the quartz-diorites, as it is a facies of a large area of that rock.

QUARTZ-MICA-DIORITE (GRANODIORITE).

Excepting an area just north of Scales, all the areas properly referable to the quartz-diorite family are in the eastern part of the Downieville district, where the rock is abundant. It is quite probable that all of the areas of the rock in this part of the district are actually connected, and may be treated as one large area, although the connection between these can not be demonstrated on the surface. The rocks are in general characterized by a granitic habitus, and are usually spoken of as granite. At nearly all points both hornblende and biotite are present in the rock. Plagioclase, varying from oligoclase to labradorite, is the most abundant feldspar, but some microcline or orthoclase is usually present. The interstitial quartz is in variable amount, and is the last element to crystallize. The variation in composition is well shown in the table of analyses. At two points pyroxene-diorite forms a facies of the quartz-mica-diorite. One of these is 6.1 miles southwest of Mount Ingalls, on the west slope of the Grizzly Mountains, just below the andesite-tuff area that caps the ridge. In this rock grains of brown hornblende and of pyroxene are included in a poikilitic manner in the plagioclase feldspar, which is developed in large anhedrons. There is also a garnet-pyroxene rock at this point.

[1] Mr. A. Wedderburn found No. 284 to contain 6.92 per cent of potassa and 4.86 per cent of soda.
[2] Jour. of Geology, Vol. III, p. 390; Am. Geologist, Vol. XVII, p. 379.

The other locality referred to is about Hay Press Valley, in the southeast part of the district. There is here a considerable mass of rock more basic than the quartz mica diorite, containing rhombic and monoclinic pyroxene and very little quartz. It appears without doubt, however, to grade over into the quartz-diorite. The rock was regarded at first as an augite-syenite allied to the monzonites, but further investigation shows that the amount of alkali feldspar is too small to entitle it to a place in the monzonite group. These pyroxene diorites are treated of here on account of their genetic relation to the quartz-diorites. The pyroxene-diorites referred to are represented in the table of analyses by Nos. 165 and 166 S. N. They are both from north of Hay Press Valley. In structure and in qualitative mineral composition they are strikingly similar to the monzonites from South Tyrol, but, as before stated, they contain too small a proportion of alkali feldspar. If judged by the microscope alone, one would have little doubt that the rock before him should be called a monzonite. The exact character of the later unstriated feldspar which incloses the older elements has, however, not yet been determined. It may be a soda-orthoclase; at any rate, in a few grains which show a cleavage like that of orthoclase the extinction was not parallel to the cleavage. The chemical composition of No. 165, so far as determined, corresponds very nearly with the augite-norite described by G. H. Williams[1] from New York. This augite-norite is called an augite-diorite by Brögger.[2]

Pyroxene-diorite (No. 165 S. N.).

Locality: Area north of Hay Press Valley.

Macroscopically, a dark-greenish, coarse-grained, granitoid rock, showing black mica and pyroxene-like grains.

Microscopically, the structure is hypidiomorphic. Plagioclase in multiple twins, with idiomorphic tendency; pyroxene both monoclinic and rhombic and usually nearly idiomorphic; brown mica and grains of iron ore and micropegmatite are in parts of the section inclosed in later unstriated feldspar. There is also a little quartz, perhaps later than the unstriated feldspar. The plagioclase appears to be andesine. The augite in part shows diallage cleavage. It is idiomorphic, and sometimes incloses grains of iron oxide. The rhombic pyroxene is hypersthene. The brown mica sometimes incloses grains of iron ore. The unstriated feldspar, as a rule, shows no cleavage, but with a high power are seen numberless minute interpositions arranged in parallel rows, as in faserig (fibrous) orthoclase, but the elongated interpositions are so small as to be indeterminable by ordinary optical means. They are best seen by nearly closing the diaphragm below the stage, causing the light to strike the section at an angle. The feldspar extinguishes in some anhedrons when these delicate lines of interpositions are parallel to the cross hair, and in other anhedrons when at an angle. Becke[3] described similar interpositions in a potash feldspar, and showed them to be albite or albite-oligoclase. Apatite is present in minute prisms. Fig. B, Pl. XLII, shows the idiomorphic character of the augite.

[1] Am. Jour. Sci., Vol. XXXIII, p. 193.

[2] Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo, 1895, p. 57.

[3] Min. und petrog. Mitth., 1881, p. 197.

No. 166 S. N., from the same area as 165, is similar in structure. It is a light-gray, coarse-grained, granitoid rock. The angite usually shows the diallage cleavage, but some of it is altered to uralite and chlorite. A part of the plagioclase is labradorite. Nearly all of the grains of iron oxide are inclosed in biotite. Apatite is quite abundant, in rather stout, irregular, and small idiomorphic prisms.

Forming dikes in the quartz-mica-diorite at many points are light-gray rocks, usually showing no ferromagnesian element. These are granulites or aplites, and are closely related in origin to pegmatites, both rocks being often found in the same dike. East of Milton, a dike of a diabase porphyry (No. 226) and another of granulite (No. 227) are intrusive in the quartz-diorite (No. 225).

In the table of analyses, No. 71 is regarded as the most nearly typical of the rock which has been termed granodiorite on the geologic maps. The author is not inclined, however, to permanently adopt this term, as the descriptive term quartz-mica-diorite appears to be sufficiently definite. The Juratrias rocks of the Milton series seem to have been altered by the quartz-diorites, and the tuffs of the Robinson formation (Upper Carboniferous) at the southwest base of Mount Ingalls have likewise been altered along the contact, and, moreover, are included in the granitic rock as fragments. The age of the quartz-diorite eruptions is therefore placed at about the close of the Juratrias or very early in the Cretaceous.

Analyses of the quartz-diorite series.

	Pyroxene-diorites.		Quartz-mica-diorites.			
	No. 165 S. N. *a*	No. 166 S. N. *b*	No. 225 S. N. *c*	No. 345 Plumas. *d*	No. 359 Plumas. *d*	No. 71 S. N. *c*
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silica	55.04	62.56	57.26	59.83	67.02	67.33
Lime	....	5.50	6.69	6.19	1.42	1.09
Magnesia	3.11	....	3.41	....	....	1.63
Potassa	1.11	2.81	2.93	1.69	2.72	2.46
Soda	1.27	3.12	2.65	3.53	3.70	3.76

a Stokes, analyst. *b* Steiger, analyist. *c* Hillebrand, analyst. *d* Hillebrand and Steiger, analysts.

QUARTZ-DIORITE-PORPHYRY.

As noted under "Granite," there are about Indian Valley very numerous white dikes cutting nearly all the other rocks of that neighborhood. The microscope shows these dikes to be porphyries, having a microcrystalline to cryptocrystalline groundmass composed of allotriomorphic grains of quartz and feldspar, in which are embedded idiomorphic phenocrysts of feldspar, biotite, and hornblende, with occasional quartzes. A complete analysis of one of these dikes (No. 304 S. N.) will be found in the table of analyses of the quartz diorite family. These dikes are particularly well exposed in the rocky bed and banks of the North Yuba.

east of the valley. At one point, about 1,400 feet upstream from the mouth of Humbug Creek, cutting the black, hardened slates, several of these dikes (No. 290 S. N.) were noted from 2 to 10 feet apart, all with a parallel strike toward about 77° west of south, or nearly east and west, dipping to the north at angles of from 60° to 70° from horizontality. The strike of the slates is here about N. 3° W., and their dip 60° to 70° to the east. Such a series of dikes may be presumed to have a common source at some point not far below the surface, and may be called a multiple dike. At other points a few hundred feet west of the multiple dike similar dikes were noted, some of them intruded parallel to the strike of the slates. The dikes vary in thickness from a few inches to 15 feet.

Quartz-diorite-porphyry (No. 304 S. N.).

Locality: Dike cutting the granite of Indian Valley near the east border of the area, on the north bank of the North Yuba. There were several of these dikes, from 3 inches to 3 feet in diameter.

Macroscopically, it is a medium-grained gray rock with small porphyritic crystals of feldspar, black mica, and hornblende.

Microscopically, the rock is composed of very fresh and beautifully twinned phenocrysts of feldspar, often with marked zonal structure, brown-green hornblende in elongated idiomorphic prisms, and numerous foils of biotite in a nearly cryptocrystalline groundmass, which is composed of minute allotriomorphic grains, presumably of both quartz and feldspar. Such a rock may, perhaps, be more correctly called a dacite-porphyry, but most of the dikes show a distinctly microcrystalline groundmass in which both quartz and feldspar can be determined. The feldspar phenocrysts are plagioclase. They are twinned on the albite and Carlsbad laws. Many of them are hexagonal in cross section.

Analysis of quartz-diorite-porphyry.

[Analyst, Hillebrand.]

	No. 304 S. N.
	Per cent.
Silica	66.65
Lime	4.44
Magnesia	1.26
Potassa	1.70
Soda	4.59

No. 584 S. N. is from a dike in serpentine on the north bank of the river, just west of the Indian Valley granite.

No. 301 S. N. is a dike in the massive greenstone that forms a layer in the Calaveras formation just east of the Indian Valley granite area, on the north bank of the river.

These quartz-diorite-porphyries occur also in other portions of the Downieville area. About the south end and along the east shore of Gold Lake they form irregular dikes, at points inclosing fragments of the greenstone. A dike 2½ feet thick was also noted in the greenstone breccia south of the Bear Lakes. The strike of the dike (No. 206 Sierra Co.) is nearly east and west, cutting across the apparent bedding (schistosity?) of the greenstone.

On the north slope of Washington Hill, about 2 miles south of Limestone Point, there were two dikes noted (No. 89 S. N.), which widened rapidly from a few feet to nearly 100 feet.

In the bed of Rock Creek, about one-fourth mile downstream from Scales, the slates are cut by a quartz-diorite-porphyry dike about 40 feet wide.

The similarity in composition of these dikes to the quartz-mica-diorites (granodiorite) suggests a direct genetic relation, but no observations have been made which show such a relation to exist.

The structure of the quartz-diorite-porphyry is shown in the photomicrograph of No. 298 S. N. (Pl. XLIV, B), which is from a dike in the bed of the North Yuba referred to under diorite-porphyry.

OPHITOID QUARTZ-AUGITE-DIORITE.

The dike of a quartz-porphyry-like rock (No. 251 S. N.) that cuts the Calaveras formation northwest of Sierra City, just east of the quartz vein of the Sierra Buttes gold mine, appears to represent a peculiar quartz-diorite in which the feldspars are lath-shaped, penetrating the quartz in an ophitic manner. Judging from the amount of secondary products, epidote and uralite, this dike contained originally much pyroxene.

A similar dike (?) (No. 598 S. N.), but with much less quartz, occurs at the Kentucky quartz mine, on the south slope of the Sierra Buttes, east of Sierra City.

On the north slope of Eureka Peak, included as blocks (No. 383 Plumas) in the quartz-porphyry, is a rock containing primary quartz grains which partly inclose lath-shaped feldspars. The former ferromagnesian silicates are now represented by epidote and chlorite.

In the granitic area of Harris Meadows, 6 miles southeast of Downieville, are numerous small, green dikes in which the metasilicate (augite) is still fresh. The close resemblance in structure of these dikes (No. 216 S. N.) to the quartz-diorites above noted renders it probable that the entire series originally contained augite. No. 216 shows likewise an ophitoid structure, the lath-shaped feldspars penetrating both the augite and the quartz. Iron-ore grains are abundant, altering to a white product, presumably leucoxene. A good idea of the structure of the above rocks may be obtained by inspecting the photomicrograph of No. 550 Calaveras (Pl. XLVI, B), which appears to be an inclusion in quartz-diorite-porphyry in the area of the Jackson sheet, although the exposure was not satisfactory and there is some doubt as to the relation of the two rocks.

DIORITE-PORPHYRY.

Forming narrow dikes in this, as in most other areas, is a dark rock, usually showing numerous minute hornblende needles. The structure of these dike rocks usually is more or less nearly panidimorphic, the porphyritic brown hornblende being usually quite idiomorphic and the feldspar often so.

On Pl. XLIV, A (No. 298 S. N.), is shown a photomicrograph of one of these diorites. No. 298 forms a border along a dike of quartz-diorite-porphyry in the bed of the North Yuba, about 1,200 feet downstream from the mouth of Humbug Creek. This rock was at first thought to be salband to the quartz-diorite-porphyry dike, but a narrow inspection, both of the hand specimen and of the thin section under the microscope, shows a sharp separation of the two dike rocks, and makes it probable that they represent two distinct intrusions.

No. 283 S. N. is from a dike of one of those diorites, which cuts other dikes on the south side of the North Yuba, just west of the Indian Valley granite area. As noted under pyroxene-syenite, these white dikes may be either that rock or quartz-diorite-porphyry, a specimen of one of the particular dikes cut by dike No. 283 not having been collected.

No. 134 S. N. is from a dike cutting an area of chlorite and talc schists and serpentine on the north slope of the ridge, $1\frac{1}{4}$ miles southwest of Bunker Hill.

This dike, which is about 3 feet in diameter, lies rather flat. The microscope shows needles of brown hornblende embedded in a finely granular feldspathic base, which is obscured by a meshwork of minute, brightly polarized fibers, probably talc or sericite.

No chemical analyses have been made of any of these dikes in the Downieville area.

Accompanying the serpentine dikes on the west slope of the Sierra Buttes ridge are numerous dioritic dikes containing idiomorphic primary hornblende. These are more evenly granular than the dikes described above (see No. 221 S. N.), but may be related to them genetically. Presumably they are intrusive in the serpentine.

GABBRO.

As limited by the writer, the feldspar of gabbro should be chiefly of the labradorite-anorthite series. In several of the areas called gabbro the feldspar is altered to saussurite, and is therefore not determinable. All of the rocks here called gabbros are medium to coarse grained, and with one exception (No. 892) of even texture. As noted under serpentine, there are frequently gabbro masses in the serpentine dikes that cut the eastern part of the large area of the Calaveras formation. The area that lies just east of the serpentine dike south of Goodyears Bar is composed of hornblende-gabbro, some of which contains secondary quartz. To the east of this area, along the North Yuba and on the ridge north and south, is a peculiar garnetiferous quartzite-like rock, greatly crushed and altered, which may be a product of silicification of the hornblende-gabbro. (See specimens 198 and 213 S. N.) This siliceous rock is, however, placed in the Calaveras formation.

On the east slope of Eureka Peak is an area of gabbro (No. 158 Plumas), and along its west contact with the quartz-porphyry of Eureka Peak pieces of the gabbro are inclosed in the porphyry, showing the gabbro to be the older rock. A small mass of a similar gabbro lies about a mile north of the summit of the peak, and another little area about a mile southwest of Bunker Hill.

A narrow gabbro dike about 2 miles long cuts the Calaveras formation a little east of Downieville.

By far the most interesting gabbro area is that lying in the Willow Creek drainage east of Penman Peak. On the north it is in contact with an area of quartz-mica-diorite. This gabbro area was referred to in the previous report as exhibiting in places an orbicular structure. The orbicular rock itself contains olivine and iron ore with much rhombic pyroxene and anorthite, but the average rock of the area is a normal gabbro composed of monoclinic pyroxene, brown hornblende, iron ore, and basic plagioclase. In some specimens there are large porphyritic hornblendes more than an inch long. The orbicules are not all round, as the name would indicate. One (No. 892*c* S. N.), that has a kidney shape, is pictured on Pl. XXX, B.

The analysis (No. 892) is of a piece of an orbicule which is made up of layers of olivine, hypersthene, iron oxide, and a little plagioclase with intervening layers, chiefly of basic plagioclase, and with pyroxene in minor amount. Some monoclinic pyroxene and brown hornblende are also present.

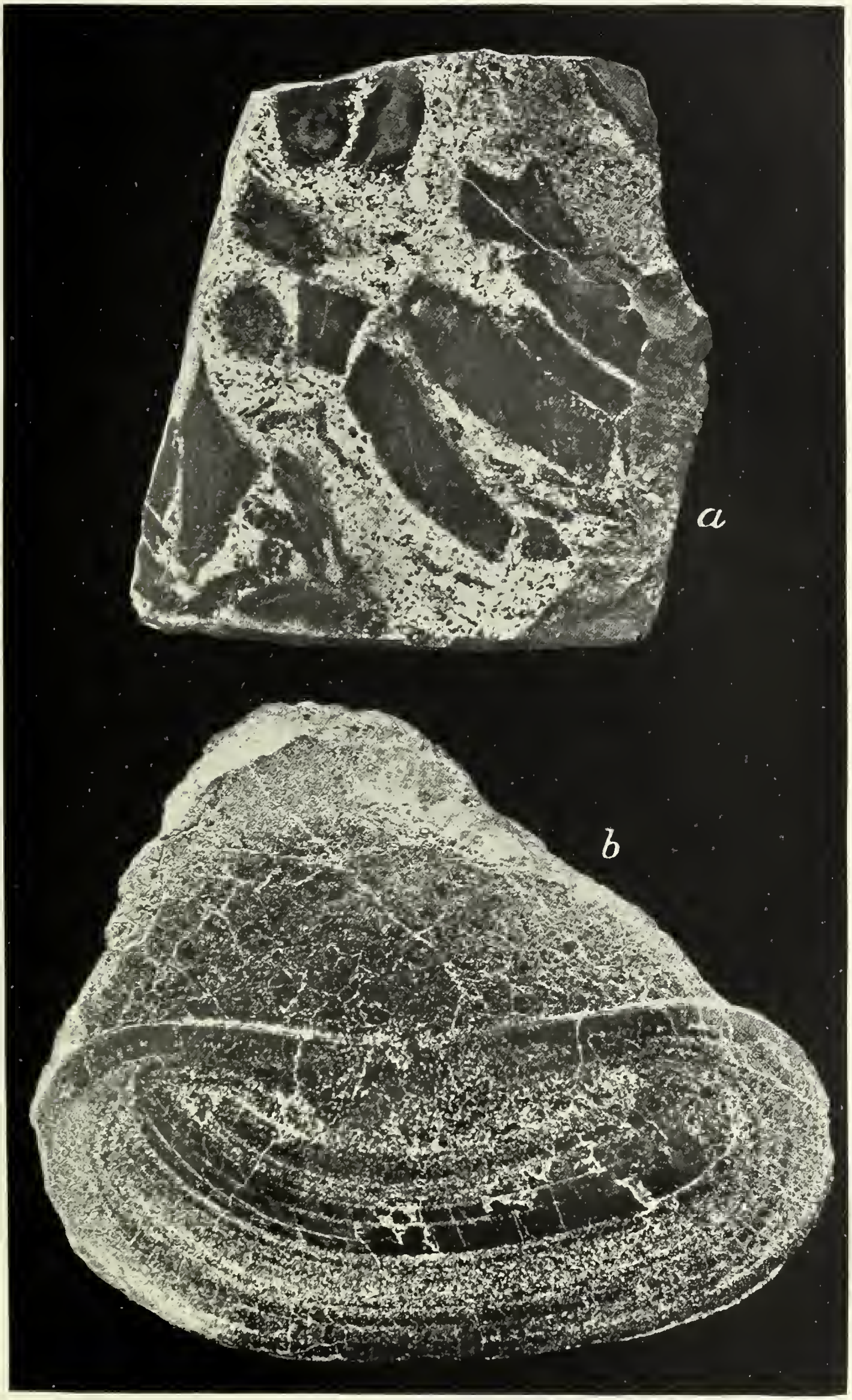
An important work on orbicular rocks by Dr. von Chrustschoff has lately been published. In his enumeration of localities of orbicular rocks Dr. von Chrustschoff gives only one place where an orbicular gabbro has been found, namely, Romsås, Norway.[1]

Analyses of gabbros.

[Analysts, Hillebrand and Steiger.]

	No. 892 S. N.	No. 158 Plumas.
	Per cent.	*Per cent.*
Silica	45.92	53.14
Lime	9.96	9.56
Magnesia	13.85	4.97
Potassa	.10	1.54
Soda	.71	1.75

[1] Ueber holocrystalline makrovariolitische Gesteine, von Dr. K. von Chrustschoff, St. Petersburg, 1894, 4°, p. 7.



a. GRANITIC CONTACT-BRECCIA.
b. ORBICULAR NORITE.

THE AUGITIC GREENSTONE SERIES.

Under this heading will be grouped a series of old lavas, tuffs, and dikes which in most cases show fresh augite, and which in all cases can be shown to have been originally augitic rocks. Most of these rocks are of Juratrias age, but as the age of certain of the areas is in doubt, no age is assigned them on the geologic map. The series, as a whole, shows much less evidence of compression than the greenstones included under amphibolite, although the two series represent originally similar rocks, and it is by no means unlikely that original augite may be found in some of the areas marked as amphibolite. Uralite is, however, present in a variable quantity in nearly every specimen, and often epidote and chlorite, but, as a rule, the larger augites are still fresh.

The augitic tuffs noted under quartz-porphyry as overlying the quartz-porphyry breccias form part of an area that broadens in the lake region, having a width in the latitude of Gold Lake of about 5 miles. Considerable masses of this greenstone seem to represent massive lava flows, as at Mount Elwell. To the north of the lake region the greenstones are buried under the large morainal area about Johnsville, reappearing about 1½ miles north of that town and continuing to Long Valley, north of which they are again hidden by andesitic tuffs for a space of about 3 miles, then broadening again to the very large area that forms a part of the summit and much of the western slope of the Grizzly Mountains. If this greenstone area is actually connected as indicated, and all parts are of one age, there is suggested the possibility of a synclinal structure to this portion of the district. To the south of the Johnsville morainal area we have an easterly dipping series, as follows:

1. Quartz-porphyry and quartz-porphyry breccia, with siliceous argillite lenses.
2. Greenstone series.
3. Milton series.

In the Grizzly Mountains to the south of Pine Creek we have a westerly dipping (vertical along the summit) series as follows, beginning on the east:

1. Quartz-porphyry.
1*a*. Siliceous argillite.
2. Greenstone series.

The probability of the entire greenstone belt (2) being continuous and of the same age is considerable. The same can not, however, be said of the quartz-porphyry series of the Sierra Buttes ridge and the Grizzly Mountains. As previously stated, it is not impossible that the siliceous argillite of the Grizzly Mountains is of Silurian age.

About one-half mile southwest of Mount Elwell, by the trail to Long Lake, there is a small dike of an augite-porphyry or greenstone (Nos. 204 and 205 Plumas) in a small lens of siliceous argillite. Fragments of the argillite are to be seen in the porphyry. Near Wades Lake, greenstone dikes, some of them 15 feet in width, are abundant in the schistose quartz-porphyry, as noted in the previous report. At the west end of Wades Lake, and extending north and south up the slopes, is a mass of limestone with a little siliceous argillite and conglomerate.

Dikes of greenstone 100 feet in diameter cut this limestone. At the contact of the magnesian limestone series and quartz-porphyry by Jamison Creek, south of Eureka Peak, numerous dikes of greenstone cut both formations. A greenstone dike (No. 179 Plumas) cuts the marble that has been quarried on Little Long Valley Creek.

About 1.2 miles southwest of Bunker Hill, on the north slope of the ridge, is a mass of quartz-porphyry associated with talc and chlorite schists. This quartz-porphyry mass is cut by a greenstone dike (No. 133 S. N.) which the microscope shows to be composed of plagioclase laths embedded ophitically in chlorite, which may represent original augite, so that the dike may be an altered diabase. These dikes give additional evidence, therefore, of the later age of the greenstones of the east part of the Downieville area.

The greenstone area to the east of Little Grizzly Creek contains abundant large squarish crystals, which the microscope shows to be uralite paramorphic after augite.

Forming a dike that crosses Canyon Creek 1 mile upstream from Poker Flat, at a point where there is a cascade in the creek, is a dike of a green rock that the microscope shows to be a diabase with ophitic structure. The augite is pinkish, and some of it is fringed with uralite fibers. The ilmenite is in part altered to leucoxene, and there is much chlorite present.

No. 320 Plumas is a fine diabase with the augite wedged in between the feldspar laths. This is from Little Grizzly Creek, about one-fourth mile south of the fortieth parallel. The augite has an idiomorphic tendency. There is abundant iron ore present, and apatite, some of it in very delicate needles, one of which has a length of .12 mm. and a maximum breadth of .0012 mm., or a length 100 times its width. Chlorite, calcite, and epidote are present as secondary products. The area represented on the map from which this specimen came is, however, a mixed one, and there is probably little true diabase in it.

DIABASE-PORPHYRY.

Along Howard Creek, bordered on the west by the large area of augitic greenstone of Juratrias age that extends nearly across the area of the sheet, and on the east by a strip of sedimentary deposits presumed to belong to the Milton series, is a lens of a porphyritic rock about 1½ miles in length. The most noticeable feature of this rock (No. 246 S. N.) is the dark (whitish, when weathered), tabular feldspars, often half an inch in length. Under the microscope the groundmass is seen to be microcrystalline, and to be made up of grains and laths of feldspar, grains of iron ore and of an augite-like mineral, and minute pleochroic prisms that extinguish at an angle and appear to be hornblende, perhaps secondary. The small size of the augite-like grains makes their determination doubtful. The large feldspars are twinned on the Carlsbad and albite laws. Two of these, cut approximately normal to the twin plane (010), were examined. One proved to be andesine and the other labradorite. A piece of the rock was broken up and fragments of the large feldspars were picked out. These were subjected to a partial analysis by Dr. Fireman, of the Columbian University, with the following result:

Feldspar from diabase-porphyry (No. 246 S. N.).

	Per cent.
Silica	51.65
Lime	9.70
Potassa	1.01
Soda	1.92

While not agreeing rigidly with the theoretic composition of any feldspar, it is evident that this feldspar is near labradorite. These phenocrysts are very abundant in the specimen, and indicate a basic character for the rock. In some of them a little iron ore (magnetite or ilmenite) and a little uralite replacing augite were noted.

No. 192, Sierra County, is from a dike (?) on the north slope of the ridge about 3 miles north of the No. 246 area, by the trail from Gold Lake to Wash post-office, in Mohawk Valley. In this rock the porphyritic feldspars of a greenish white color are being altered to a saussuritic material. On the east side of Mohawk Valley is a considerable area of a fine-grained rock, in a portion of which similar tabular plagioclase phenocrysts are developed, although of smaller size. The rocks (Nos. 104–106 Plumas) are more altered in this area, containing much brownish-green secondary mica, sericite, epidote, and uralite. The uralite in part has replaced former augite (?) phenocrysts.

The rocks above described as diabase-porphyries are essentially identical with the labrador-porphyrites of Rosenbusch, as exemplified by Nos. 173 and 174 in the Voigt and Hochgesang collection, which illustrate Rosenbusch's Massige Gesteine. The sections in the set belonging to the United States Geological Survey are more altered, however, than the rocks from Plumas County.

LATE DIABASE-PORPHYRY DIKES.

In the quartz-mica-diorite 6.7 miles southeast of the Sierra Buttes, or to the east of Milton, is a dark-green dike (No. 226 S. N.) along a dike of granulite (No. 227 S. N.). The dark-green dike is a porphyry with a fine holocrystalline groundmass of feldspar, iron ore, and secondary brownish mica and uralite, with fresh phenocrysts of labradorite, and augites which are in some cases fresh at the center but are chiefly altered to uralite grouped in radiating brushes. This rock may also be called a diabase-porphyry (or a basalt-porphyry?). An analysis will be found in the table of analyses of the gabbro family.

A similar dike (No. 45 S. N.) was found cutting the Milton formation south of Milton.

Capping the highest peak of the Sierra Buttes, according to Mr. Lindgren, is a green rock containing abundant fresh augite phenocrysts in a groundmass that appears to be holocrystalline. It is a diabase-porphyry or a basalt-porphyry.

QUARTZ-PORPHYRY (RHYOLITE-PORPHYRY).

The rocks so designated form considerable areas in a belt extending north and south across the middle of the Downieville area. In almost any hand specimen there are numerous porphyritic quartzes to be seen. In the larger part of the quartz-porphyry a schistose structure has been developed, coincident in strike and dip with the schistosity of the neighboring areas of sedimentary rocks and greenstones. The prevailing color is a very light gray, nearly white when massive, but much of the schistose quartz-porphyry, as at Bunker Hill, has a bluish tinge. When occurring in small amount in the other rocks, the color and aspect of the rock are less characteristic and the croppings frequently resemble those of the surrounding rocks, but in general one can tell at a glance what the rock before him is. Dikes of this rock in the Paleozoic (?) sedimentary series were found at various points. Those near Wades Lake follow the stratification where noted, but southwest of the Sierra Buttes and at other points dikes cutting the slates at an angle were found.

Extending from a point on the east slope of the Grizzly Mountains to the north of the fortieth parallel, in a nearly south direction, passing just east of Tower Rock and thence across the crest of the Grizzly Mountains down the west slope to Long Valley Creek, is a long, narrow area of the quartz-porphyry. This is believed to represent a surface flow. A secondary schistose structure has been developed in much of the area, the dip being often to the west and always at a high angle. The age of this lava is uncertain, but immediately west is a long, narrow area of siliceous argillite similar to that which Mr. Diller found north of the fortieth parallel associated with Silurian limestone. The age of this siliceous argillite strip in the Downieville area must, however, for the present remain an open question, as it pinches out to the southeast of Tower Rock, and its relation to the Silurian siliceous argillite (Grizzly formation) has not been made out.

No. 323 Plumas in the table of analyses is from this quartz-porphyry area. A complete analysis of the same rock by Dr. Hillebrand will be found in the chapter on the classification of the rocks.

An area of a similar schistose quartz-porphyry extends from Eureka Peak to the ridge south of Sierra City. It forms the main mass of the Sierra Buttes, and as a portion of the area is distinctly a breccia it is supposed to be likewise chiefly an effusive mass. In the table of analyses, Nos. 119, 384, 153, 288, and 128 are from this area.

The contact of this quartz-porphyry with the Paleozoic (?) sediments lying to the west is usually sharp. The Paleozoic series referred to was called in a previous paper[1] the magnesian limestone series. It may be older than the Carboniferous, but from lack of positive evidence is mapped as part of the Calaveras formation. There can be no doubt that some of the quartz-porphyry is of later age than the magnesian limestone series, as dikes of it are common in that series, particularly to the west of Sierra City, on the slopes of the canyon of the North Fork of the Yuba. One of these (No. 222 S. N.), from the dike by the trail to the Keystone mine from Logansville, has been partially analyzed chemically. Another dike (No. 229 S. N.) is beautifully exposed in the bed of the Middle Fork of the Yuba about one-half mile west of Milton. It has a width of about 40 feet and contains abundant inclusions of the black argillite which it has intruded. A smaller dike, about 1 foot in diameter, was noted at the same point, cutting in part across the schistosity of the argillite.

Just southwest of Wades Lake is a dike of the quartz-porphyry (No. 129 Plumas) about 8 feet wide, in the sedimentary series. This shows in thin section a spherulitic structure.

Two and a half miles from the summit of Clermont Hill, on the top of its high northwest spur, is a small area of quartz-porphyry. There is another mass on Jamison Creek, 4 miles northeast of Eureka Peak, and a large area between Massick and Squirrel creeks, about 1½ miles northwest of the Spring Garden ranch. As may be seen by examining the geologic map, the main quartz-porphyry areas of the Downieville district form an interrupted belt extending across the area of the sheet in a north-south direction a little to the east of the middle of the district. It is likely that these effusive rocks were all erupted at about the same period.

As may be seen under the heading "Juratrias beds," there are, in the quartz-porphyry, lenses of siliceous argillite which may be of Juratrias age, and if the quartz-porphyry is a surface flow this would indicate likewise a Juratrias age for that rock. The following partial analyses will give the reader an idea of the composition of these acid rocks. They are plainly not typical quartz-porphyries or rhyolite-porphyries, as the average alkali content is too small. On the other hand, the silica percentage is very high for dacites or quartz-porphyrites.

Analyses of the quartz-porphyries (aporhyolite-porphyries).

	No. 222 S. N. *a*	No. 323 Plumas. *b*	No. 149 S. N. *c*	No. 384 Plumas. *d*	No. 153 Plumas. *d*	No. 288 Plumas. *d*	No. 128 Plumas. *d*
Silica		73.25	73.52	73.62	75.06	76.69	79.41
Lime		2.23	4.13	2.55	.38	.97	.09
Potassa	2.46	3.79	.96	2.23	4.27	2.29	2.75
Soda	2.50	2.69	2,98	2.46	3.78	4.62	2.81

a Wedderburn, analyst.
b Hillebrand, analyst.
c Steiger, analyst.
d Hillebrand and Steiger, analysts.

[1] Jour. of Geology, Vol. III, p. 398.

Some brief descriptions of the microscopic features of these rocks will be found in the author's paper in the Fourteenth Annual Report. A very considerable portion of the quartz-porphyry series is much altered and is quite schistose, the dip of the schistosity being often vertical.

The relation of the quartz-porphyry breccia to the overlying greenstone tuffs on the east slope of the Sierra Buttes is described under the heading "Juratrias beds." A considerable portion of the quartz-porphyry of the Sierra Buttes and the ridge extending thence north to

FIG. 20.—Columnar Juratrias lava.

Eureka Peak is regarded as a massive flow, and as underlying the quartz-porphyry breccia beds. However, it can not be said that the field examination was sufficiently thorough to determine whether this holds throughout the area. The breccia beds, moreover, contain some fragments and layers of more basic lavas. One of these layers (No. 141 S. N.) exhibits a columnar structure, the columns standing approximately vertical while the stratum as a whole dips at a considerable angle to the east. The locality is about one-half mile southwest of Upper Salmon Lake. Fig. 20 is from a photograph of this columnar lava. Underlying this stratum is a quartz vein dipping east at an angle of about 45°, along which extends a dike or thin sheet from 8 to 10 inches in diameter. A tunnel had been run in to exploit the quartz vein. Taken in connection with the interbedded siliceous argillite of the Deer Lake clastic area, which would underlie this columnar lava, and the apparent bedding of the tuffs about the Salmon lakes before described, this quartz vein will appear to have been formed along a bedding plane, or, to speak more correctly, the lower flow surface of the columnar lava sheet. The writer therefore regards the entire tuff series from the top of the ridge north of Deer Lake to Lower Salmon Lake as conformable, dipping to the east at an average angle of perhaps 45°. This comparatively low easterly dip will explain likewise the marked easterly extension of the boundary line between the quartz-porphyry tuffs and the overlying augitic tuffs, which about Upper Salmon Lake have been removed by erosion.

So far as the writer's observations go, there are no evidences of original stratification to be noted in the tuff series about Gold Lake and from there northward. Secondary structures (schistosity and fissure systems) only were observed.

THE ALTERED IGNEOUS ROCKS.

THE MAGNESIAN SERIES.

The same association of magnesian rocks so characteristic of large areas in the Bidwell Bar district obtains only to a limited extent in the Downieville area, where serpentine is the chief magnesian rock represented. The largest area is a huge dike-like mass which, with perhaps some interruption, extends across the area of the sheet from the Colfax district. It crosses the North Yuba at Goodyear Bar, Canyon Creek at Poker Flat, Mount Fillmore on its west slope, broadens to the northwest of Onion Valley into an area 4 miles wide, extends across the canyon of the Middle Feather, through Meadow Valley in the Bidwell Bar area, across the North Feather and its branches, forming in the Lassen Peak area the point known as Red Hill, and to the west of the North Feather disappears beneath the Tertiary lavas of the Lassen Peak area.

From specimens collected at many points it is known that the mother rock of this serpentine dike is a peridotite, or in places (see Bidwell Bar area) a pyroxenite. Remains of olivine and pyroxene are still to be seen in the thin sections.

One mile west of the St. Charles ranch the rocks of the dike (?) are chiefly talc and chlorite schists.

The following are specimens from this area:

Pyroxenite (No. 399 Plumas.)

Locality: From the south slope of the Middle Feather Canyon.

Microscopically, it is composed of pyroxene grains, apparently enstatite, altering to tremolite.

Pyroxenite or peridotite (No. 397 Plumas).

Locality: From about one-half mile south of Onion Valley.

Microscopically, it is chiefly made up of colorless monoclinic pyroxene. Minute veins of serpentine cut the pyroxenes, and there is serpentine apparently forming around grains of pyroxene. This serpentine may, however, have resulted from olivine grains now completely gone.

Hornblende-pyroxene rock (No. 154 Sierra County).

Locality: From Goodyear Creek 1 mile north of Oak ranch.

Microscopically, it is made up chiefly of large anhedrons of brown hornblende inclosing rounded grains of monoclinic pyroxene. There is a saussuritic aggregate between some of the hornblende grains that may represent original feldspar, in which case this rock is allied to the hornblende gabbros (see Nos. 201 and 204).

Peridotite (No. 177 Sierra County).

Locality: From about 1,000 feet south of Poker Flat.

Microscopically, it is composed of pyroxene, in part monoclinic, and olivine, the latter plainly altering to serpentine along a network of cracks. With the serpentine are streaks of magnetic iron oxide, with some chromic iron, the latter being somewhat translucent and showing a brown color by transmitted light, while the magnetite is opaque. Many of the grains of monoclinic pyroxene are likewise, but to a less extent, intersected by a network of cracks filled with serpentine.

On the west slope of Clermont Hill white dikes of granulite cut the serpentine, and 2 miles south of Limestone Point there are in it large dikes of quartz-diorite-porphyry.

There are several dikes of serpentine, usually but a few hundred feet in width, in the eastern part of the large area of the Calaveras formation that covers such a large portion of the Downieville district. Two of these dikes have a length of about 4½ miles. Certain less altered portions of these dikes are gabbro (see Nos. 220, 238, and 239 S. N.), in which the diallage is chiefly fresh, but altering around the edges to fibrous hornblende, and the feldspar is entirely gone and replaced by saussurite and epidote.

Apparently intrusive in the mother rock of the serpentine dikes of the west slope of the Sierra Buttes are dikes of diorite-porphyry containing idiomorphic primary hornblende.

The small area about 1¼ miles southwest of Bunker Hill is composed of serpentine and talc-schist. These rocks are cut by a diorite-porphyry dike.

The area of magnesian rocks that surrounds the south half of the Indian Valley granite mass is an interesting one. To the west of the valley, serpentine, talc-schist, and chlorite-schist occur together, and here may be seen white dikes in abundance cutting the series. These dikes are treated of under the head of pyroxene-syenite-porphyry and quartz-diorite-porphyry.

The following are specimens from the Indian Valley area:

Peridotite (No. 302 S. N.).

Locality: From the narrow strip of serpentine by the North Yuba just east of the Indian Valley granite.

Microscopically, remains of the original minerals are to be noted, but these grains look more like pyroxene than olivine. There is some colorless amphibole and a little calcite or dolomite. Fibrous serpentine with blue-gray interference colors is the most abundant secondary product, but iron oxide and iron disulphide are also abundant. The chemical analysis indicates that olivine must have been present.

Analysis of peridotite (No. 302 S. N.).

[Analyst, Steiger.]

	Per cent.
Silica	38.94
Iron oxide	9.96
Lime	.11
Magnesia	39.71

Peridotite (No. 307 S. N.).

Locality: From the south side of Indian Hill, where hydraulic washing has cleared off the gravel—that is to say, in the bed-rock of the gravel mine.

Microscopically, as seen without the analyzer, the rock is composed of translucent olivine-like grains, separated by anastomosing cracks filled with darker material and translucent patches containing a fibrous material. With the analyzer the olivine-like grains are seen to be independently oriented. The rock may represent a peridotite with granulitoid structure. The translucent patches are made up of a meshwork of talc-like scales which is penetrated by colorless amphibole needles. A curious vein, with a light-brown convoluted border, apparently chrysotile, cuts the section. Forming an inner coating to the light-brown border is a dark greenish-brown layer, from which innumerable minute clear crystals project into the clear interior.

Chlorite-schist (No. 308).

Macroscopically, this is a fine-grained, schistose, greenish-blue rock, forming seams in serpentine No. 307.

Microscopically, it is made up chiefly of thick scales of highly pleochroic (blue-green) chlorite and calcite or dolomite.

There are a few streaks of serpentine along Spring Garden Creek, downstream from Pine Creek, one of which (3½ miles northwest of the Spring Garden ranch) forms a dike in the slates, extending south up the ridge slope, but with this exception the serpentine is confined to the southwest half of the area.

AMPHIBOLITE AND METADIORITE.

Under this heading are grouped much altered igneous rocks now chiefly characterized by an abundance of green aluminous hornblende, usually of the fibrous uralite type, but in part a thoroughly recrystallized hornblende. Some of the areas appear to have been originally augitic tuffs and surface lavas. Such is the greenstone west of Laporte and its continuation to the southeast, and most of the material in the southwest corner of the Downieville area. It is possible that some of these streaks of greenstone—for example, those northwest and south of the Eureka gravel mines—were layers of volcanic material laid down in water. Some of these areas are difficult to separate from the distinctly sedimentary material. Just west of Scales the indurated sedimentary rock contains a good deal of secondary hornblende. However, the original sedimentary nature of this material seemed so certain that it is entered as part of the Calaveras formation.

On the west flank of Clermont Hill, to the east of the serpentine area, is a lens of a coarse amphibolite-schist. In it are veins of a peculiar blue quartz (No. 458 Plumas). The microscope shows the dark color of the quartz to be due to very abundant minute black grains whose nature was not determined. Another area is crossed by the South Fork of the Feather River to the east of Little Grass Valley. In it are dikes of a coarse-grained rock (No. 97 S. N.), composed of a very white feldspar, pretty certainly albite, and the same peculiar blue quartz that occurs without any feldspar in the hornblende-schist of Clermont Hill, suggesting a genetic connection between the blue quartz vein and the soda-granulite dikes that are found at numerous points in the serpentine area of the west slope of the hill. Besides the two areas noted above, there is a much larger mass of this peculiar hornblende-schist between Gibsonville and Canyon Creek. On the ridge north of Canyon Creek, at most points noted the schist has a nearly east-west strike, and it will be observed on the geologic map that its south border has the same strike. The sedimentary schists on the ridge south of Canyon Creek are likewise displaced in the same manner. It is likely that the original rock of this schist is not the same as that of the uralite and epidote schist at Laporte and other points. The hornblende of the coarsely fibrous schist just described is a deep-green, aluminous variety. A partial analysis of it was made by Mr. George Steiger. The specimen was a chip of No. 278 S. N., taken by the ditch on the north slope of Canyon Creek, 1 mile due east of Grass Flat. The hornblende was not separated from the other constituents, and the analysis can not be used to determine its exact nature, but as the other constituents—quartz, epidote, and a few grains of pyrite—do not constitute more than one-tenth of the rock, there can be no doubt that the hornblende contains a high percentage of alumina and iron.

Analysis of amphibolite-schist (No. 278 S. N.).

	Per cent.
Silica	48.21
Titanic acid	1.84
Alumina	11.26
Iron oxide	11.54

Just south of the bridge over the east branch of Slate Creek, by the road from Howland Flat to Gibsonville, there is a streak of quartz-schist, in part garnetiferous, in the coarse amphibolite-schist just described. This is too small to be indicated on the map.

ECONOMIC GEOLOGY.

GOLD GRAVELS.

The gravels of the Tertiary rivers have already been described. Besides the ordinary "bars" and gravel in the stream beds, the soil and loose material itself have been mined, particularly on the ridge 3 miles east of Gold Lake. The Hayes mine at this point has proved very profitable. Some years since a shaft was sunk in the middle of the American Valley, but little if any gold was taken out. Along the canyon of the North Yuba at Downieville and at other points may still be seen remnants of gravel benches which were formerly extensively mined with good returns.

GOLD IN QUARTZ-PORPHYRY (RHYOLITE-PORPHYRY).

One mile east of Onion Valley is a dike of rhyolite-porphyry in the Auriferous slate series, at the head of Poorman Creek, in a decomposd portion of which free gold occurs, associated with little veins of quartz. As the gulch was very rich below this dike (No. 400 Plumas), it is possible that much of the gold in it came from the dike. At the time of the writer's visit the gravel and morainal débris about the gulch was being mined by the hydraulic method by Mr. Thomas, the owner of the claim, two gold bricks, of the value of about $5,000, attesting to the richness of the gravel. This gold deposit is of unusual interest, as being in a dike of late Cretaceous or Tertiary age. The rock may be termed a rhyolite-porphyry. It is composed of crystals of brown mica, sanidine, plagioclase, and quartz, in a finely micogranular groundmass of apparently both quartz and feldspar.

GOLD IN QUARTZ VEINS.

No portion of the Sierra Nevada is more prolific in quartz veins than the Downieville area. Large and continuous veins are, however, not the rule, and the mines as a whole have not proved nearly so rich as in other districts. The most notable mines are those on the east slope of Eureka Peak, known as the Plumas Eureka, and the Sierra Buttes mines, northwest of Sierra City. These have been worked with much profit for many years, but are now nearly exhausted. According to Mr. J. A. Edman, the vein matter in the Plumas Eureka consists of a firm, white quartz, carrying a large percentage of pyrite, with galena and some zinc-blende, the gold being about evenly distributed through the quartz and the sulphides. To the south of the Plumas Eureka the Little Jamison quartz vein is said to promise well.

The Sierra Buttes vein is a large one, in places 40 feet in width, dipping to the east at from 40° to 50°. It was worked for many years with large profit.

The Young America vein, on the east slope of the Sierra Buttes, was a soft, brittle quartz, with porphyry walls, and is said to have paid from $20 to $30 per ton. The quartz contained very little sulphide, the ore being free milling. According to Mr. Lindgren, the pay chute was narrow on top and widened out below, being 400 feet wide in places. The vein in general varies from 6 to 12 feet in width. The Mountain mine, on the spur south of the Sardine Lakes, produces a high-grade ore. Like the Young America mine, it is most picturesquely located.

The Phœnix mine, on the southeast slope of the Buttes, is another valuable property, but has not been working lately so far as known to the writer. There is considerable prospecting going on in the ridge south of Sierra City and Downieville, where quartz veins are numerous, but no mines of importance are being worked there at present. The veins occur both in the slates and in the granite area of Harris Meadows. At Gold Valley two quartz veins have been developed, the Gold Valley Mining Company's vein and the vein of the St. Johns mine; both strike northeast and dip southeast. The veins are about 5 feet wide. In the Gold Valley mine sulphides were so abundant that a chlorination plant was necessary.

Two mines have been developed on the west side of the North Fork of the North Yuba, to the north of Downieville. The Good Hope, about 500 feet above the stream, is a vein between slate and serpentine. The strike of the ledge is northwest and southeast. The Gold Bluff, farther up the ravine, is still being worked. The strike of the ledge is said to be north and south and the dip 45° to the west.

Quartz veins are abundant in the slates along Willow Creek east of Clermont Hill. For details in regard to the mines the reader is referred to the reports of the State mineralogist of California.

In the Willow Creek[1] drainage, to the south and southeast of Grizzly Hill, the gravels along the stream bed have been worked for many years with considerable profit, pointing to the existence of auriferous-quartz veins in the older rocks. No large veins have, however, been yet developed in this territory. Quartz veins are abundant on the ridge west of Willow Creek, to the south of Gravel Range, and in the vicinity of Sky High, 4 miles southeast of Merrimac. They were also noted on the south spur of Mount Ararat.

MANGANESE.

As stated under "Gold veins," there is a vein of oxide of manganese near the Diadem lode. According to Mr. Edman there is a deposit of manganese ore about three-fourths of a mile due south of Edmanton. This is known as the Penrose lode, and is located on the economic

[1] This is not the same Willow Creek as the one just noted.

sheet of the Bidwell Bar folio of the Geologic Atlas of the United States.[1]

According to Mr. Edman the Penrose lode is made up of quartz and psilomelane. It may be traced northwesterly as far as Eagle Gulch. Lenticular bodies of manganese (pyrolusite and psilomelane) are met with in the soft talc slates found between the iron vein and the Diadem lode.

IRON ORE.

There is a mass of magnetite by the creek north of Gold Valley, the surface of which has been smoothed by glacial action. On this surface are numerous figures drawn in former times by the Indians. This mass is noted on the economic sheet of the Downieville folio (in preparation), as is also another smaller mass just southeast of the Spencer Lakes.

CHROME IRON.

In the gravel of Goodyear Creek waterworn pebbles of chrome iron have been found. These doubtless came from the neighboring serpentine area. Similar pebbles from the gravel at Howland Flat indicate bodies in place not far away, as the pebbles are too heavy for distant transportation under ordinary circumstances.

LIMESTONE AND MARBLE.

The very abundant limestone masses that form a zone in the Paleozoic slates just west of the quartz-porphyry belt of Eureka Peak and Sierra Buttes are chiefly of a dirty light-gray color. Another similar mass is found on the main southeast spur of Clermont Hill, and is known as Limestone Point. Analyses of two samples of these limestones are given in the paragraph on the Calaveras formation, and show that they are highly magnesian. On Little Long Valley Creek is a mass of crystalline limestone or marble. Some of this has been burned for lime.

THE SIERRAVILLE SHEET.

The area covered by the Sierraville sheet lies immediately east of the Downieville district. One of its marked features is Sierra Valley, the southwestern part of which is at times submerged. In this valley the Middle Feather has its source. Artesian water has been struck at many points in deep wells. One flowing well, on the north side of the valley, may be seen by the road from Chat to Beckwith. At the northeast side of the valley lies the Beckwith Pass, having an elevation of about 5,300 feet. This is said to be the lowest pass in the range, and to be comparatively free from snow in winter, making it a desirable route for a railroad.

Humbug Valley, in the northwest corner, contains lake sediments deposited by the same body of water that filled Mohawk Valley in Pleistocene time.

[1]The manganese, chromite, and magnetite deposits near Meadow Valley were noted on the economic sheet of the Bidwell Bar folio from information furnished by Mr. Edman.

The larger part of the area is composed of granitic rocks, and where these have been observed in the western part of the district they are of the quartz-mica-diorite type. This is the case west of Sattley by the road to Sierra City, about Humbug Valley where exposed, and by the road from Beckwith to Red Clover Valley. In the granite about one-fourth mile northwest of Beckwith post office, to the north of the road to Mohawk Valley, is a dike of greisen or quartz-muscovite rock which contains grains of a biaxial topaz-like mineral (No. 58 S. N.). Topaz is a common constituent of dikes of this nature.

Overlying the granite and associated older rocks are very extensive areas of Tertiary lavas. The portion of the area south of Sierra Valley, the district lying west of Sierra Valley of which Beckwith Butte is the most prominent point, and the ridges between Red Clover Valley and Sierra Valley are largely covered with these lavas. The lava of the summit of Beckwith Butte is a basic andesite with phenocrysts of labradorite, augite, and hypersthene in a glassy groundmass. On the north and east flanks of the butte are some areas of rhyolite, which is evidently older than the andesite that forms much of its upper portion.

An interesting dike is exposed along the Middle Feather about one-half mile west of the mouth of Big Grizzly Creek. Along the roadbed of the Mohawk Valley Railroad the dike has been cut through, making an exposure of about one-fourth of a mile of fresh rock. The rock of the dike is a basic porphyry, containing much brown hornblende and some augite, with traces of an apparently glassy base, now devitrified. The feldspars range from labradorite to anorthite, and compose much the larger portion of the rock, placing beyond doubt its basic nature. The dike is particularly interesting from containing numerous angular inclusions of a more coarsely crystalline rock of the same nature as the general rock of the dike. A hand specimen showing one of these inclusions is shown in Pl. XXIX, B. The inclusion is largely made up of brown hornblende and basic feldspar. These inclusions seem to represent an earlier crystallization from the same magma as that of the general dike rock. The dike is presumably pre-Tertiary in age. The high ridges along the eastern portion of the area appear to be chiefly granite.

The southern part of the district has been somewhat examined by Mr. Lindgren, who will later publish some notes about it.

CHAPTER V.

DISTRICT SOUTH OF THE COSUMNES RIVER.

GENERAL REMARKS.

The district to the south of the Cosumnes River, or approximately of 38° 30′ north latitude, has been in part studied in detail. The writer's notes on the Jackson area have already been published, and the geological field work of the Sonora area is complete. A reconnaissance has been made of a considerable portion of the Oakdale, Merced-Mariposa, Big Trees, Dardanelles, Yosemite, and Mount Dana areas, and some notes have also been made on the geology of the Kaweah River drainage. The material gathered in the course of these explorations has not been thoroughly elaborated and classified. Moreover, it is expected that much additional information concerning this portion of the range will be acquired in the near future. However, as it may be some time before this material is in shape for publication, it is thought best to present here some of the writer's notes, although these are not well systematized.

THE JACKSON AREA.

Practically no further information has been obtained concerning the Jackson area than that published in the text accompanying the Jackson folio[1] and the notes in the Fourteenth Annual Report.[2] Attention should, however, be called to the granitoid rock areas southeast of Milton and north of Jenny Lind. These rocks were called coarse-grained quartz-porphyrites in the former publications. In reality they are typical quartz-diorite-porphyries. Occurring apparently as an inclusion in the porphyry (No. 1689 S. N.) is a rock (No. 550 Calaveras) which appears to have originally contained augite. The lath-shaped feldspars penetrate the primary quartz and the secondary (?) hornblende in an ophitic manner. This rock is very similar to that of the dikes described as ophitoid quartz-augite-diorite in the Downieville area. A photomicrograph of a thin section of this rock is shown on Pl. XLVI, B.

Another correction of more importance relates to the age of the strip of slates that ends on the map exactly on the southeast corner of the

[1] Geologic Atlas of the United States, Jackson folio, California (folio 11), Washington, 1894.

[2] The rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, pp. 435-495.

sheet. If the Jackson geological map is examined, it will be noted that just west of it is an elongated area of greenstone (*db*). On account of the general resemblance of these slates to those of the Mariposa formation lying immediately west, and because of the reported find of an ammonite by Whitney[1] in the continuation of these slates at Robinsons Ferry, on the Stanislaus, these slates are colored on the map as part of the Mariposa formation. Last summer, on Mormon Creek, in the Sonora area, at a point directly in the strike of these beds, limestone croppings in the slates were found in which were round crinoid stems indicating a probable Paleozoic age. Moreover, at no point in the vicinity in slates known certainly to belong to the Mariposa formation has any limestone been found. In the northwest continuation of the slate area here referred to, about 1 mile southwest of Angels, there is a small lens of limestone, as noted on the Jackson map. There is then a probability that this strip of slates, about one-half mile in width, should be colored as belonging to the Calaveras formation, although the mere presence of the limestone lenses and the absence of limestone in general from the Mariposa formation must be regarded as evidence of a second order. As may be noted in the description of the Sonora area, there is some limestone south of the Merced River in slates that probably belong to the Mariposa formation.

THE SONORA AREA.

As already stated, the field work in the Sonora area is practically finished, and complete notes concerning it will be published with the folio. In the meantime a few general statements may be made concerning the district. As a whole, the geology of the district is very similar to that of the Jackson area, nearly all of the formations represented on that sheet being also found in the Sonora district.

NEOCENE RIVER GRAVELS.

The deposits of the Tertiary rivers have been largely removed by erosion. The best-preserved channel is that underlying the Tuolumne Table Mountain. According to Professor Whitney[2] the lava that caps this mountain forms part of a flow that originated high up in the mountains, beyond the Calaveras groves of *Sequoia gigantea*, or big trees. A portion of the flow is preserved on the north side of the Stanislaus. It is said to have crossed the space now occupied by the Stanislaus Canyon just below Abbys Ferry. From southwest of Columbia at all events the flow may be traced, with minor interruptions, to a little east of Knights Ferry, at the edge of the San Joaquin Valley. The old river gravel under the lava has been extensively mined in all that portion of the channel that is in the Sonora area.

[1] Auriferous Gravels, p. 41. As may be seen by referring to Geology of California, Vol. I, p. 261 Robinson's Ferry is the ferry across the Stanislaus south of Carson Hill, and here the belt of slate referred to crosses the river. Robinsons Ferry is in the southwest corner of the Big Trees area.

[2] Geology of California, Vol. 1, p. 243.

There are larger masses of Neocene river gravel on the ridge just south of the Tuolumne River, between Groveland and Colfax Gate. Some of the masses known as the Dorsey mines have been extensively hydraulicked. South of Hamilton's ranch on the west side of Moore Creek is a long narrow area of gravel which Mr. Ransome traced nearly continuously for 2 miles or more. The elevation of this channel is less than that of the larger channel of the Dorsey mines. Three and a half miles northeast of Colfax Gate are some bodies of gravel which may have been deposited by the same river as that which deposited the Dorsey mines gravel. There are some patches of river gravel and scattered pebbles on the flat at the head of Corral Creek, but no well-defined channel was found.

NEOCENE GULF DEPOSITS.

In the southwest part of the area of the sheet there are extensive hills made up of andesitic gravel and sand, with some pumice-like layers. These deposits were doubtless formed at about the same time as the andesite-tuffs, or probably in Pliocene time. Underlying the dark series containing the andesitic sediment are light-colored sandstones and clays, which are presumed to represent the Ione formation (probably Miocene). The series is finely exposed on the north side of the Tuolumne River opposite and northwest of Lagrange, and at various points between Lagrange and the Merced River. At most of these places there are none of the later andesitic sediments overlying the supposed Ione beds, but a little west of a line joining Lagrange and Merced Falls the andesitic beds overlie the light-colored series. As a rule the Ione sandstones of the area are not found at a greater elevation than 400 feet, while the known Tejon (to be noted later) is from 500 to 700 feet in elevation.

TEJON FORMATION (EOCENE).

On the south side of the Merced River opposite Merced Falls is a very noticeable flat-topped sandstone hill, the sandstone and conglomerate layers resting nearly horizontally on slates of the Mariposa formation. Just southwest of the main hill is a little flat-topped butte made up of the same sandstone. Here several years ago Mr. James E. Mills, of Quincy, Cal., collected in the sandstone some fossil shells which he referred to Prof. J. P. Smith, of Stanford, who reported them to be *Cardita planicosta* Lamarck, a characteristic Eocene fossil.

In 1895 the writer visited the locality and obtained some of the fossils, concerning which Dr. Dall states:

> They prove to be much crushed specimens of *Venericardia hornii* Gabb, *planicosta* Lam. var., and indicate for the rock in which they occur an age corresponding to the Claibornian (Middle Eocene).

AURIFEROUS SLATE SERIES.

What may be regarded as the oldest sedimentary series consists of a wide belt of quartzites and mica-schists which form the high eminence known as Duckwall Mountain and Mount Lewis and extend southerly and westerly to the horizon of the Sonora limestone belt. This limestone belt appears to be the same as that at Hites Cove, in Mariposa County, for there is a series of limestone lenses nearly in a line extending from Sonora to Hites Cove. As Carboniferous fossils have been found in the Hites Cove limestone, it is assumed that the entire belt is of that age, and the siliceous rocks lying to the east and north of this belt are regarded as an older series. At Sonora a nearly inclosed protrusion of the large granite mass of the Sierra has cut off this siliceous series, the granite being practically in contact with the limestone belt. This inclosed granitic area in its form of occurrence is remarkably similar to the area at West Point, shown in the Jackson folio, which likewise cuts through a similar highly siliceous series reaching down to the same limestone belt. A remarkable feature in the limestone mass south of this granite area, where it strikes nearly east and west, conformably with the strike of the granite contact, is the existence of fingerlike (as seen in horizontal projection on the geologic map) protrusions of limestone into the schists along the Tuolumne River, these protrusions diverging perceptibly. The manner of the divergence of these layers of limestone from a large, solid mass into the schists may be compared, as to form of occurrence, with dikes extending into the surrounding rocks from an igneous massive. In the case in question the present position of the limestone layers can not be explained by faulting, for the limestone dips and strikes with the sedimentary schists, the dip being chiefly to the north at an angle of more than 50°, and if the beds were placed in their original horizontal position these limestone layers would be superimposed, one directly over another.

Northeast of Carter post-office, on the west slope of the North Tuolumne, are gneissoidal rocks containing some layers made up of wollastonite and garnet very similar to the supposed Archean gneisses of the Big Trees area. There are some similar gneissoidal rocks in the bed of the Middle Tuolumne, upstream from the mouth of Reed Creek.

The district west and southwest of Sonora has been chiefly investigated by Mr. F. L. Ransome.[1] The rocks are highly compressed and contain large amounts of igneous material.

There are here rich gold mines, part of the Mother lode belt, which extends thence southeast across the area of the sheet. To the west of the belt of Mariposa slates which lies along the Mother lode are extensive masses of augitic lavas and tuffs of presumably Juratrias age. To the west of this greenstone belt is a narrow belt of clay-slates and sandstone, from 1 to 2 miles to the west of which is another large area of tuffs, more acid than that west of the Mother lode, and this is succeeded by a third belt of slates, which are presumed to belong to the Mariposa formation. The middle belt of clay-slate and sandstone appears to strike into that belt of the Mariposa formation which may

[1] Mr. Ransome mapped also the entire western border of the area and a strip across the middle in an east-west direction.

be seen at Salt Spring Valley in the Jackson area, and which crosses the Stanislaus just west of Byrnes Ferry bridge. In the southeast extension of this belt, in the neighborhood of Hornitos, are highly altered schists which appear to be of the same age, and are perhaps to be regarded as the result of contact metamorphism produced by a basic igneous rock, some of which is a typical diabase, of which there are numerous areas in this vicinity. However, the case is not a clear one. there being no very extensive masses of the diabase, but rather very abundant dikes and irregular intrusions, and as nearly the entire mass of the schists to the northeast of Hornitos is more or less thoroughly crystalline, their present metamorphic condition is ascribed with some reservation to the intrusion of the basic rocks, the largest area of which is about 3 miles in length and half a mile in width.

On Cotton Creek, in the belt of sediments just described, is a lens of limestone, some of which has been used to make lime.

At the mouth of Sullivan Creek the Mariposa slates are finely exposed, and in places are much sheared and folded, which is quite unusual with the slates of that formation. A very evident cleavage cutting the bedding planes was noted. The original lines of bedding are very distinctly shown by their sandy layers in the slate or shale. On account of the much fractured condition of the shale it was difficult to obtain a specimen showing this phenomenon, but a sketch by Mr. Ridgway of the specimen obtained illustrates the structure fairly well. This sketch is reproduced in fig. 21. The somewhat lenticular sandy layer at the base of the specimen and a few faint parallel streaks in the upper portion show the lines of original bedding. The slaty cleavage shown by the fine lines cutting the bedding planes at an angle seems not to have been noticeably developed in the lower sandy layer.

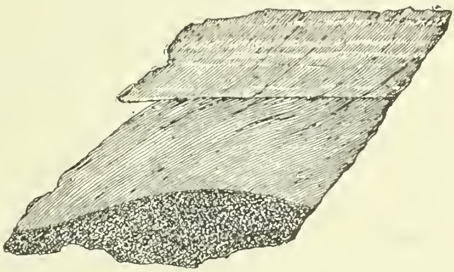


FIG. 21.—Piece of Mariposa slate showing slaty cleavage cutting the sedimentation planes.

The zones of shearing are shown in fig. 22, which is from a sketch of a hand specimen. In this the planes of bedding are parallel to the flat surface of the specimen, and the zones of shearing cut directly across the original bedding.

On the west side of Woods Creek, at the mouth of Sullivan Creek, is a conglomerate stratum in the Mariposa beds. This contains pebbles of white and blue quartzite or vein quartz, of ordinary quartzite, of devitrified pre-Cretaceous andesites showing flow structure in the groundmass, of granite-porphyry-like rocks much sheared, containing muscovite, and of black siliceous argillite. This may perhaps be regarded as a basal conglomerate.

The following notes on the Auriferous slate series are by Mr. Ransome:

"Some difficulty was experienced in separating the area of Calaveras slates to the west of Tuttletown in the extreme northwest corner of the sheet from the Mariposa slates adjoining them on the west. The line as drawn is somewhat arbitrary, but fairly defines the boundary between slates of somewhat heterogeneous character on the east and the ordinary uniform clay-slates of the Mariposa formation on the west. Some small lenses of limestone containing round crinoid stems were considered as indicating that this eastern portion belonged to the Calaveras formation.

"The eastern belt of the Mariposa formation consists chiefly of dark clay-slates, but contains also a good deal of fine gray sandstone, usually in rather thin beds, intercalated with the slates. The existence of these sandstone beds permits the observation to be made that with very rare local exceptions the slaty cleavage is parallel with the original bedding. The sandstones themselves usually show a marked fissility par-

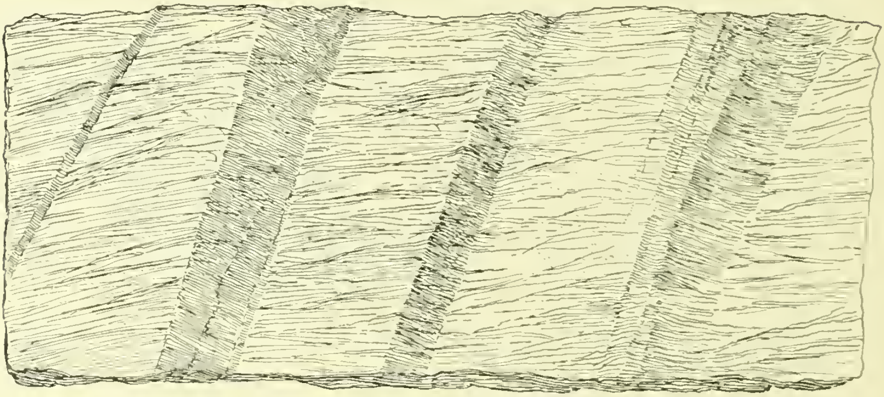


FIG. 22.—Specimen of Mariposa slate showing planes of shearing.

allel with their bedding planes. The prevailing dip of the slates and sandstones is northeasterly at considerable angles, but on Woods Creek, near Jacksonville, a distinct anticlinal structure is discernible, the beds on the eastern side of the creek dipping to the east, while those on the west dip westerly. In general, however, the closely compressed beds, with northwest-southeast strike and steep northeasterly dips, do not allow the recognition of anticlinal or synclinal structures.

"On the east side of the Pena Blanca Ridge, about 4 miles northeast of Coulterville, the belt of slates is cut in two by an area of serpentine at a point where the latter comes in contact with the great mass of augite-porphyrite which makes up the Pena Blanca Ridge. This is the only interruption to the otherwise continuous belt of Mariposa slates extending diagonally across the sheet. It is possible, however, that at this point a very narrow strip of the slates may be concealed beneath the loose fragments of augite-porphyrite, thus preserving the actual continuity of the belt—a possibility that is indicated upon the map.

"The great quartz veins making up the famous Mother lode follow in a general way this eastern belt of Mariposa slates, but within the area assigned to the writer they lie usually just to the east of the belt, frequently separated from it by serpentine or some other intrusive or igneous rock."

PRE-CRETACEOUS INTRUSIVE IGNEOUS ROCKS.

QUARTZ-PYROXENE-DIORITE.

The large granitic area in which are the mines of the Soulsbyville district is not a true granite or a typical granodiorite. Much of the area contains pyroxene and grades over into rocks some of which may be monzonite, which is an augite-syenite rich in plagioclase. Some of them may be called pyroxene-diorites, the pyroxene being both augite and hypersthene. In nearly all of them more or less quartz is present. To the east of the Phœnix reservoir is a very basic mass, probably a gabbro, the relation of which to the quartz-pyroxene-diorite was not determined, except that the two masses are in contact. There are very numerous dikes of diorite-porphyry in these granitoid rocks, analyses of two of which, Nos. 935 and 938, may be found in the table of diorite family analyses in Chapter III.

In the table of analyses of quartz-diorites may be found an analysis (No. 936 S. N.) of the quartz-bearing pyroxene-diorite from a little south of the road to Soulsbyville, about 1½ miles southeast of Sonora, at which point Nos. 935 and 938 were also collected.

AUGITE-SYENITE.

North of Carter post-office, on Turnback Creek, was collected a specimen of a peculiar dike rock, which the microscope shows to be an augite-syenite (No. 950 S. N.). This is the second dike of this rock found by the writer, the other being No. 284, from near Indian Valley, in the Downieville area.

SODA-FELDSPAR DIKES.

Forming numerous dikes along the belt of quartz mines of the Mother lode are white rocks which at some points contain quartz and muscovite, but which at many points are made up chiefly of feldspar. The microscope and chemical analyses show that the feldspar is chiefly albite, and they therefore belong to the soda group of syenitic rocks. Dikes rich in soda-feldspar have been found to be directly associated with gold deposits in Eldorado County,[1] and it was therefore of interest to note a similar association in the Sonora area. In the dikes in Eldorado County the dike material itself, or altered portions of it, with infiltrated quartz, forms the lode in which the gold and sulphides are found. Certain evidence of gold occurring directly in the dikes in the Sonora area was not obtained, but at a number of points the dike material had evidently been regarded as ore, though the absence of the miners prevented the obtaining of detailed information.

[1] Am. Jour. Sci., Vol. XLVII, 1894, p. 470.

Along the Bachelor gold vein, on the north bank of the Tuolumne River, 2 miles southeast of Jacksonville, are several soda-feldspar dikes, which are in part penetrated by secondary quartz veinlets, and contain dolomite and iron disulphide. Directly west is the vein of the gold mine, concerning the value of which the writer has no information. The property is as yet quite undeveloped. The vein lies at the contact of a body of serpentine on the west and a body of clay-slate or schist, probably of Carboniferous age, on the east. The slates dip N. 30 E., at an angle of about 65°. The vein itself is composed of white quartz, dolomite, and mariposite, a micaceous mineral often of a bright-green color. Just east of the vein, in the clay-schists, within a width of 30 feet, are the dikes referred to, six or eight in number. These usually run parallel with the strike of the schists, but at two points they cut across the schistosity. Such a series of dikes might be called a multiple dike, following Lawson,[1] as it is reasonably certain that at some depth below the surface they all come together. The dikes vary from 2 inches to 2 feet in width. Quartz veinlets, one with a convoluted course, cut both the schists and the dikes. Between the dikes and the ledge is a broken-up mass of the dike rock, of a reddish-brown color, penetrated by quartz veinlets and seams of dolomite, and apparently in a fair way to form a quartz vein, like that immediately west, if the alteration should go further. This mass seemed a friction breccia, and would indicate movement and faulting along the vein. A microscopic examination of this breccia showed it to be made up of fragments of the dike rock, cemented by dolomite and quartz. Throughout the rock, as well as in the dikes just east, are scattered iron sulphurets (FeS_2), in minute specks. The brown color is due to abundantly disseminated limonite. The microscope shows the dike rock, where not replaced by silica and dolomite, to be composed almost entirely of interlocking grains of feldspar, with some larger twinned feldspars, all the feldspars containing numerous grains of carbonate. They are, in fact, identical as to composition with other similar dikes, which may be seen along the Mother lode, a mile to the northwest, or about a mile due east of Jacksonville, and to the east of Moccasin Creek, on the south side of the river.

The dike to the east of Moccasin Creek also contains, at several points, numerous quartz veinlets. In the bed of Moccasin Creek, at its mouth, is a large cropping of white granitoid rock. This is the north end of the Moccasin Creek dike, which extends thence nearly or quite continuously southeasterly for about 2½ miles. It crosses the road to Groveland about one-third of a mile east of the bridge over Moccasin Creek. Except at the north end, it lies entirely to the east of the creek, gradually increasing in altitude and in distance from the creek to the southeast. This dike was first noted by the writer in 1886, but no investigation was made as to its nature. It is mentioned by H. W.

[1] Am. Geologist, Vol. XIII, p. 293.

Fairbanks in a paper on the Mother lode,[1] but was called by him a granite dike, which rock, indeed, it resembles to the naked eye, and, as noted above, the north end of the dike is a soda-granite or aplite, as the terms are used by Rosenbusch, or a soda-granulite according to Michel-Lévy. Specimens of this dike were collected at a number of points. The granitoid portion at the north end contains a good deal of quartz, and may be called a soda-granulite or aplite. It is composed of quartz, muscovite, and albite or soda feldspar. An analysis of this soda-granulite is given in the table of analyses of the syenite family in Chapter VI (No. 1523 S. N.). By far the larger part of the dike, however, is made up of albite feldspar only, and is mostly finer grained than the granitoid rock at the north end. It may be designated a soda-syenite (albitite)-porphyry. Thin sections from different portions of the dike show a somewhat different structure and composition, but the variation is small. The porphyry is made up chiefly of interlocking grains and prisms of albite, often untwinned, and in some sections there are definite phenocrysts of polysynthetically twinned feldspar (probably likewise albite) developed. Rather abundant in some specimens is an olive-green mineral, in grains and prisms. The extinction is sensibly parallel to the prism, and the interference colors are bright. But one cross section showing beyond doubt the nature of the cleavage was found. In this section the two sets of prismatic cleavages intersect at nearly right angles. The mineral is presumed to be ægirite. These dikes, therefore, show some analogy to certain dikes in Norway, described by Brögger, and called by him sölvsbergite. The variety found near Lougenthal[2] is composed chiefly of albite, but contains also microcline, hornblende (katoforite and some arfvedsonite), ægirite, traces of biotite and quartz, accessory apatite and zircon, and occasional minute grains of a perovskite-like mineral. In the Norwegian dikes also the feldspars have a tabular habit. Pl. XLIII, A, is a photomicrograph of a thin section of No. 46 Tuolumne Co., which is from the same dike here described, the specimens being taken near where the dike crosses the road to Groveland. Pl. XLIII, B, shows another photomicrograph of another portion of the same section, taken without the analyzer and showing radiating tuffs of delicate blue hornblende needles in the porphyry.

Dikes of syenite-porphyry were also noted in some siliceous argillite or thin-bedded quartzite of presumably Paleozoic age to the north of the Merced River. One of these dikes, about 9 miles southeast of Coulterville, in a much decomposed condition, can be traced for a mile or more with a strike to the west of north. The soft, decomposed dike material has apparently been auriferous, as numerous cuts have been made in it, and claims located. As this particular dike was not investigated chemically or optically, it is quite possible that it contains some

[1] Tenth Ann. Rept. State Min. California, p. 45.

[2] W. C. Brögger, Die Gesteine der Grorudit-Tinguait-serie, Christiania, 1894, p. 76.

free quartz and is more nearly related to No. 1639 than to the soda-syenite porphyry of Moccasin Creek.

In the canyon of the Merced, on the steep west bank of the river just downstream from the mouth of the North Fork, are from fifteen to twenty white dikes from 6 inches to 6 feet in width. These dikes are nearly vertical, following the dip of the schists (75° E.), but at other points they cut the latter at a slight angle. This group of dikes may be also called a multiple dike. A thin section from a similar dike, probably a continuation of one branch of the multiple dike, taken just opposite on the east side of the river (No. 1639), shows a few twinned needles of a pale-brown hornblende and numerous idiomorphic phenocrysts of plagioclase in a microcrystalline granular groundmass of feldspar, muscovite, and probably quartz, for the silica content (71.88 per cent) is too high for all the silica to be in the constituents mentioned. In the table of albite analyses given in Dana's Manual of Mineralogy, 69 per cent is the highest amount given, and it is therefore evident that if a no more basic element than albite were present the silica percentage could scarcely reach the amount found by Mr. Steiger in the rock. Nevertheless, no quartz was certainly microscopically determined in the rock. The feldspar phenocrysts are, many of them, twinned on the albite law, giving symmetrical extinctions on the trace of the twinning plane (010) of from 6.5° to 21°, the average angle of nine crystals measured being 13°; none were detected showing certainly albite and Carlsbad twinning combined, so that the new method of Michel-Lévy[1] for determining feldspars could not be applied. From the lime percentage of the rock (2.03 per cent), and from the general tendency of the more basic feldspars to crystallize first, and the apparent formation of epidote directly from the feldspar phenocrysts, it is presumed that they are near andesine in composition. The rock may be provisionally called a soda-granite-porphyry.

Along the borders of the serpentine area from 6 to 7 miles southeast of Coulterville are several soda-syenite dikes. Some of them follow quite closely the contact of the serpentine and the adjoining rock, which, to the east of the serpentine, is a greenstone, an altered augite-andesite tuff, and to the south is the same belt of siliceous Paleozoic (?) argillite or quartzite before noted. One of these dikes apparently forms the lode of a gold deposit (No. 1555), as it had evidently been mined. It is greatly altered in places, containing much quartz, calcite or dolomite, and sulphurets.

There were some dikes in the greenstone itself. One of these shows the same pale hornblende needles found in No. 1639, and in a fresher condition.

Between the serpentine body above noted and the area of siliceous Paleozoic rocks is a white dike, 50 feet in width at one point, where it is crossed by the road from Buckhorn Mountain to a point opposite the

[1] Étude sur la determination des feldspaths, 1894, p. 33.

old Benton mill on the Merced River. This dike, in following the contact, makes an S-shaped curve.

Some of the syenite-porphyry dikes are also to be seen near the vein of the Red Bank gold-quartz mine, on the north side of the Merced River about halfway between Benton mill and Split Rock ferry.

Analyses of soda-feldspar dikes.

	No. 1521 S. N.	No. 1522 S. N.	No 1523 S. N.	No. 1639 S N.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Silica	67.53	66.81	69.66	71.88
Lime	.55	1.03	1.45	2.03
Potassa	.10	.07	2.85	1.80
Soda	11.50	11.18	4.49	5.81

The analyses of 1521, 1522, and 1523 are by Dr. Stokes, and of 1639 by Dr. Steiger.

DIABASE.

Under this head the writer desires to call attention to a dark, basic rock which occurs as dikes and bosses to the northeast of Hornitos, chiefly in a sedimentary area of black schists. An analysis of one of these dikes (No. 446) is given in the description of the Merced-Mariposa district.

These dikes are true diabases, and more basic than the rocks described by Mr. Ransome under the head of "Diabase and porphyrite." Moreover, the Hornitos diabase is later than the diabase and porphyrite or greenstone series, for it cuts that series in distinct dikes.

The following descriptions of quartz-mica-diorite, quartz-porphyry, hornblende-porphyrite, gabbro, pyroxenite, and peridotite, in the Sonora area, were written by Mr. Ransome, as also was the description of diabase and porphyrite, excepting the introductory note on the gravestone slates, and refer to areas in the district mapped by him.

QUARTZ-MICA-DIORITE.

"This rock occurs in several isolated areas of irregular shape, and generally of inconsiderable extent as compared with the porphyrites and serpentine. In general, the rock of these smaller masses has a somewhat different character from the typical granodiorite which occurs over large areas in other portions of the district, particularly in the northeast. It is characterized by its richness in hornblende, the scarcity or absence of macroscopic quartz, and the absence of recognizable orthoclase. Biotite is very rare, while it is abundant in the typical granodiorite. All the specimens examined under the microscope show a more or less advanced stage of decomposition. The feldspars are changed into fine-grained aggregates of secondary products, or sometimes show remnants of plagioclase lamellæ. Secondary quartz is abundant, and epidote is particularly common.[1] Apatite and titanite occur as accessory minerals, particularly the former, included in the hornblende crystals. The prevailing decomposition renders any accurate determination of the rocks difficult, but they would seem to be in the main quartz-diorites, with frequent more basic dioritic facies, and with little or no orthoclase or biotite.

"All the quartz-diorite in the area may be regarded as intrusive and of later age than the inclosing sedimentary and volcanic rocks. Its various facies are probably more basic peripheral portions of the larger batholitic mass of granodiorite which may underlie a part of the Sierra Nevada, and which is exposed over wide areas to the east of the Sonora sheet, the greater basicity being due to the differentiation of an originally homogeneous magma, complicated perhaps by a certain amount of fusion and assimilation of the invaded rocks.

"Excepting the area east of Sonora, the largest single mass of quartz-diorite is that lying between Coulterville and Big Oak Flat, nearly in the middle of the district. This is usually a rather dark rock, of moderate coarseness, showing abundant hornblende, dull-white feldspars, quartz, and usually chlorite and epidote. The feldspars are generally completely altered into clouded aggregates composed largely of a nearly colorless epidote or zoisite and scales of white mica. Apatite is sometimes a very abundant microscopic constituent, especially as inclusions in the hornblende crystals. On the east fork of Moccasin Creek, 3 miles due south of Big Oak Flat, a facies occurs which contains no hornblende, but is made up of feldspar, quartz, and small nests of epidote grains. The microscope shows that the rock has been subjected to much secondary action. The feldspars, where they are not completely broken down, are plagioclase.

"On Rattlesnake Creek, a little to the northwest of the above locality, the rock is a quartz-diorite, which, by secondary alterations and the acquirement of a schistose structure, appears to pass locally into an amphibolite-schist.

"The very irregular area just west of Indian Bar shows some variations, but in the main is a basic-looking, dioritic rock with abundant dark-green hornblende, frequently in idiomorphic crystals, dull feldspars, and some quartz.

"The microscope shows only occasional remnants of plagioclase and a prevailing abundance of epidote. Idiomorphic cross sections of hornblende are frequent. This rock is intrusive on the east into a fine-grained green rock, which is evidently a somewhat altered member of the diabase series, and will be described under the latter head. The association of the two rocks is so intimate at times that it becomes necessary to separate them by a more or less arbitrary line.

[1] A colorless mineral with the same habit and appearance as the epidote is abundant in some sections. It has a low double refraction, polarizing in deep blue-gray tints. It was supposed at first to be zoisite, but there seem to be gradations between it and the ordinary epidote, and it may be merely a colorless epidote. The crystal form is not well shown.

"The granodiorite of the area about 2 miles east of Don Pedro Bar resembles closely that just described.

"The most interesting area of granodiorite within the writer's portion of the sheet is that at Don Pedro Bar, where the intrusion has not only metamorphosed the adjacent clay-slates but has effected a marked displacement of the invaded rocks. The intrusive rock varies from a quartz-diorite, made up of hornblende, a predominating soda-lime feldspar, and quartz, to a quartz-mica-diorite with the addition of biotite, and resembles more closely the typical granodiorite of the Sierra Nevada than any other rock in the area. The feldspar (oligoclase?) occurs in semiporphyritic crystals more than a centimeter in length.

"Another isolated mass of granodiorite lies about 2½ miles east of Don Pedro Bar. The rock of this area appears to be a quartz-mica-diorite, with partially idiomorphic hornblendes. The biotite has been completely altered into pseudomorphs of chlorite and epidote. Some plagioclase still remains recognizable.

"Other small areas occur within the sedimentary rocks of the Calaveras formation to the east of the middle portion of the sheet.

"In general, the rocks of these areas may be characterized as dark basic diorites with abundant dark-green hornblende and little or no original quartz. The feldspars have generally disappeared, and their place is taken by secondary aggregates of epidote (or zoisite), white mica, and quartz.

QUARTZ-PORPHYRITE AND QUARTZ-PORPHYRY.

"Quartz-porphyrite will be described as forming a subordinate portion of the large diabase and porphyrite areas, in which case it is at least in part fragmental. But it also occurs in various portions of the area as dikes in the sedimentary series and in the older volcanic rocks. Such dikes are particularly abundant around the granodiorite area of Don Pedro Bar, cutting the inclosing clay-slates and fragmental porphyrites. Similar dikes also occur cutting the rocks of the Calaveras formation in the neighborhood of Hobron Mill. In these latter dikes the feldspars are generally decomposed, but appear to have been largely orthoclase, and the rock should perhaps be classed with the quartz-porphyries.

HORNBLENDE-PORPHYRITE.

"The only area of hornblende-porphyrite indicated upon the map occurs just west of Marshs Flat, on the south slope of Moccasin Peak, where it forms a small lenticular sheet within the augite-porphyrite series, and, like most of the latter, is of fragmental character. The rock is gray in color, with dark idiomorphic hornblende crystals disseminated abundantly through it. The microscope shows, besides the idiomorphic green hornblendes, some decomposed phenocrysts of plagioclase, lying in a compact crystalline groundmass.

GABBRO.

"This rock occurs only in small areas in the Sonora district and always in close connection with serpentine. The only area of sufficient size to be indicated on the map is that at Pena Blanca, near the middle of the area of the sheet. It is generally a rock of moderately coarse grain showing dull, opaque feldspars and light-green diallage. Under the microscope the rock is usually seen to be badly decomposed. The feldspars are reduced to kaolin-like aggregates and the diallage is partially changed to serpentine.

URALITE-GABBRO.

"The irregular area of rock thus indicated on the map west of the Rawhide serpentine area, and which extends southward under the basalt of Table Mountain, shows considerable variations and is generally too much decomposed to determine its original character. It is usually a fine-grained green rock, which under the microscope shows green hornblende, decomposed feldspars, and abundant epidote and calcite. Quartz is sometimes present, and where it is original the rock seems to have been a quartz-diorite, but generally it appears to be secondary. At a point on the road about 2 miles southwest of Jamestown a coarse facies of the rock is exposed, and is here made up of large, irregularly bounded crystals of dark-green hornblende and dull opaque feldspars. The microscope shows the latter to be completely kaolinized and all traces of twinning lamellæ lost. There is no quartz present. It is quite likely that the gabbro associated with the serpentine to the west of Rawhide is directly connected with this uralite-gabbro mass, as it was found impracticable to draw any definite line between them in the field. It is, moreover, possible that the entire area mapped as uralite-gabbro may not be a strict geological unit, but the general decomposed condition of the rock would render any further separation extremely tedious and unsatisfactory at best.

PYROXENITE.

"Typical pyroxenite, i. e., a rock with granular structure, composed chiefly of pyroxene, was not noted within the area studied. About 3 miles northeasterly from Coulterville, just north of the road to Dudley's, there is a small area of interesting rock (No. 1174 S. N.) made up almost entirely of hornblende and angite. The hornblende forms conspicuous rounded crystals of dark-greenish color, lying in a gray-green granular matrix of angite and hornblende. On fresh fracture the larger hornblendes show brilliant cleavage faces, and are sharply separated from the finely granular matrix. The microscope shows that the large hornblendes are pale-brown by transmitted light, with rather faint pleochroism, and are full of inclusions of the same colorless angite which makes up most of the groundmass.

VIEW IN THE FOOTHILL REGION, SHOWING THE GRAVESTONE SLATES.

"The hornblende in the groundmass frequently shows sharply idiomorphic cross sections, as do also the augites included in the porphyritic hornblende. A small amount of clear quartz was observed, filling spaces between the partly idiomorphic crystals of augite and hornblende.

PERIDOTITE.

"No areas of peridotite are indicated upon the geological map, but it occurs occasionally in small isolated masses or loose fragments in the large serpentine area west of Chinese Camp. A specimen (No. 1054 S. N.) taken from a small outcrop in the serpentine, about half a mile southwest of the latter town, is a dark gray-green, heavy rock which the microscope shows to be a fresh granular aggregate of olivine and diallage, forming a wehrlite."

PRE-CRETACEOUS EFFUSIVE IGNEOUS ROCKS.

DIABASE AND PORPHYRITE (GREENSTONE SERIES).

A very characteristic feature of the foothills of the Sierra Nevada, especially in the area of the Sonora, Oakdale, and Jackson sheets, are projecting slabs of slaty rocks, chiefly greenstones. These are often arranged in rows, and in open grassy spots remind the observer of rows of gravestones. For this reason they are sometimes called gravestone slates.

Pls. XXXI and XXXII, from photographs taken about 4 miles east of south from the Crimea House, will give the reader an idea of the general appearance of these slates, and of the vegetation of the foothills. The tree shown in the picture is a species of white oak (*Quercus douglasii*).[1] The brush in the distance is *Ceanothus cuneatus*.

"The rocks included under the head of diabase and porphyrite occur in long belts of irregular width, which are generally parallel with the belts of sedimentary rocks between which they lie. A schistose structure, in many cases determined probably by a rough original bedding, is not uncommon, and in such cases the superficial exposures show the usual steep easterly dip common to the sedimentary series, and project from the soil in long, parallel, comb-like outcrops stretching over hill and dale.[2] Massive diabase is rare in the region studied. The most common facies is a dark to light greenish augite-porphyrite, showing porphyritic crystals of dark augite lying in a very fine-grained groundmass. With a very few exceptions, all of the rocks of the porphyrite series were erupted as surface flows, and particularly as coarse tuffs and breccias, which find their analogues in the andesitic breccias of Tertiary age which now cap many of the higher ridges of the Sierra Nevada. They were on the whole probably more basic than the latter, and at the same time less uniform in character. Their clastic structure

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[1] The writer is indebted to Professor Coville, of the Department of Agriculture, for the determinations.

[2] These are the gravestone slates above described.—H. W. T.

is generally easily recognized in the field, and the microscope shows that the porphyritic crystals of augite are frequently embedded in a fragmental groundmass of which the original character is now largely obscured by secondary minerals, among which epidote and calcite are conspicuous.

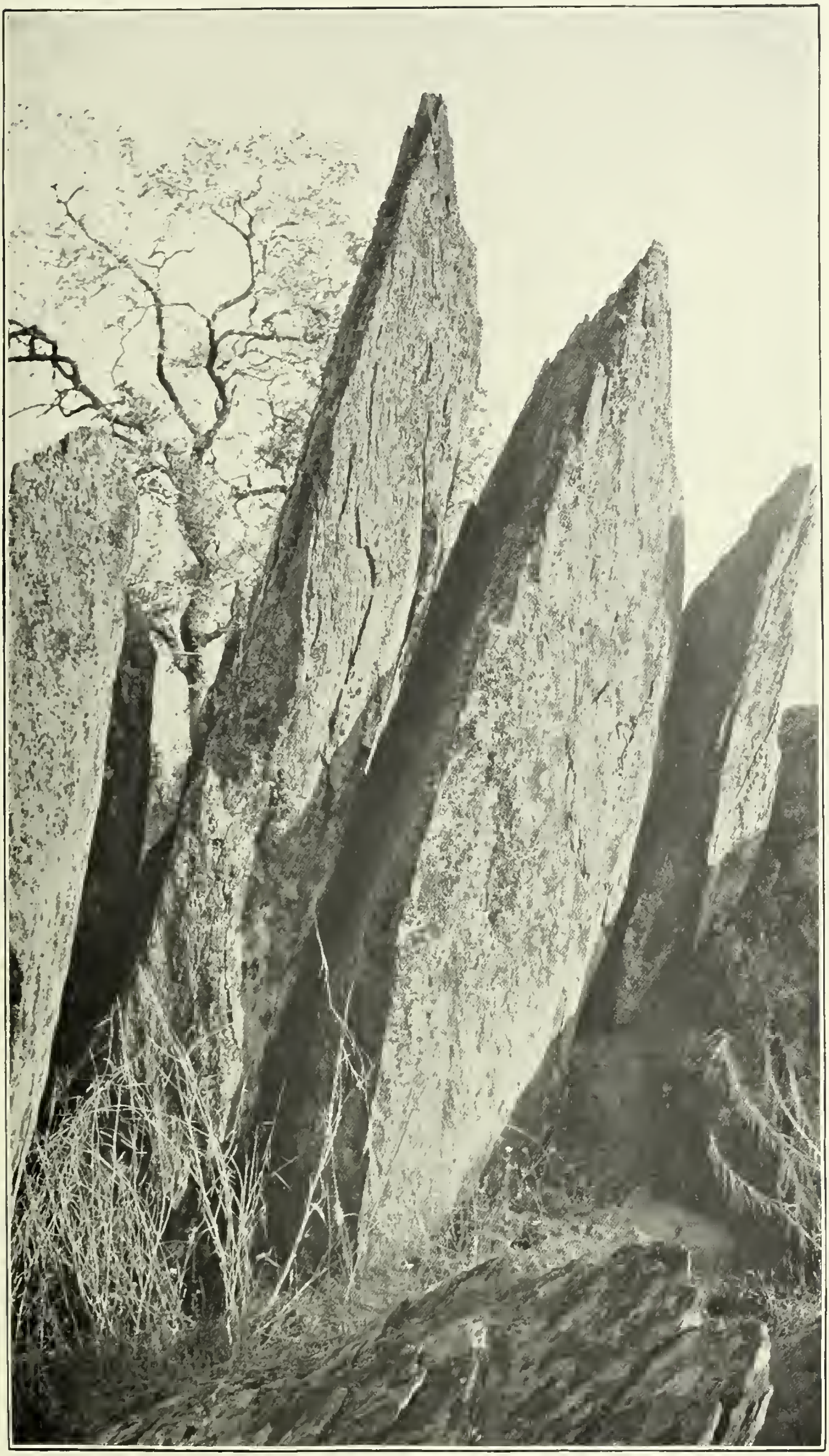
"The augitic porphyrites and the tuffs immediately associated with them have a wide distribution in the Sonora area. In a general way they form two broad parallel bands, extending diagonally across the western portion of the area of the sheet, and separated from each other by the narrow middle belt of slates and sandstones noted under Auriferous slate series.

"The eastern belt comes into the area of the sheet near the northwest corner, being probably a continuation of the Bear Mountain area of the Jackson sheet, and passes out of it near the southeast corner. For practically the entire distance, it adjoins on the west the main or eastern belt of the Mariposa slates. Considerable variation exists within this mass. At its northern end, just north of Table Mountain, it is a typical augite-porphyrite, which is locally speckled with abundant grains of pyrite. South of Table Mountain and about Chinese Camp the rock is a decomposed and uralitized but fairly typical massive diabase with ophitic structure. Farther south the cluster of rugged hills dominated by Moccasin Peak and the almost equally rugged Pena Blanca Ridge are made up of the ordinary augite-porphyrite agglomerate of coarse tuff, now consolidated into a tough rock of massive appearance. Irregular grains of quartz are fairly abundant in the augite-porphyrite 2 miles northwest of Pena Blanca, near the contact with the Mariposa slates.

"Near Indian Bar, in the western portion of the porphyrite belt, and extending over an area bounded on the west by the irregular mass of granodiorite and a narrow strip of the Calaveras formation, and on the east not always readily separated from the ordinary augite-porphyrite, there occurs a compact green rock in which the lens shows small glistening needles of green hornblende. The microscope shows that it is a compact diabase or a basalt, which has been changed into an aggregate of green hornblende needles and other secondary minerals.

"The rock was evidently originally a somewhat glassy one, as the plagioclase laths, when their form can still be recognized, show the forked and frayed ends characteristic of such rocks. This rock might be mapped as an amphibolite, but as it is not schistose, and is plainly only a uralitized portion of the diabase series, which could be separately delineated only with some difficulty, it has not been separated upon the geological map.

"The volume of these augite-porphyrite tuffs is very great. In the wider portions the belt has a width of about 5 miles, and thus, allowing for a general easterly dip of 65°, which is less than that of the inclosing sedimentary rocks, would give the enormous actual thickness of 4½



SINGLE CROPPING OF THE GRAVESTONE SLATES.

miles. The nature of the material makes it impossible to be sure that there is no folding or repetition of the single members of the series, but no indication of such duplication was observed in the field. Nevertheless, it seems hardly possible that 4½ miles can represent the original thickness of the accumulations.

"The large western area of porphyrite does not call for detailed description, as the rock resembles in a general way that of the area just described. The area may be characterized, however, as exhibiting a rather pronounced schistose structure, whereby the outcrops, although more massive, resemble somewhat those of the clay-slates.

"Moreover, by the disappearance of the augites and an increasing fineness of the tuffaceous material, with the addition of nonvolcanic detritus, these porphyrites appear to grade locally into the ordinary clay-slates of the Mariposa series.

"Other smaller areas of porphyrite tuff occur in the area studied, intercalated with the rocks of the sedimentary series. Such a strip is that lying east of Don Pedro Bar. At the Tuolumne River this is a nearly white quartz-porphyrite, but it appears to be in direct continuation with the ordinary diabase tuff which lies west of the large serpentine area near the Crimea House, and the two were not separated in the mapping.

"Although the porphyrites have been described as being chiefly fragmental in origin, it is probable that igneous intrusions in the forms of sheets and dikes helped in building up these thick volcanic accumulations, but they were certainly subordinate in volume to the purely effusive and clastic material."

ALTERED IGNEOUS ROCKS.

The following descriptions of amphibolite-schist and serpentine are by Mr. Ransome.

AMPHIBOLITE-SCHIST.

"The greater part of the green schists on the Sonora sheet form an irregular belt lying just to the east of the main belt of the Mariposa slates, and very frequently separate those slates from the rocks of the Calaveras formation to the east. The characteristic mineral of these schists is a green fibrous hornblende, but quartz, in the form of a fine mosaic of interlocking grains, plagioclase, feldspar, chlorite, epidote, biotite, white mica, and calcite, are all abundant constituents in varying proportions. Occasionally remnants of the augite and plagioclase of the original rock occur; for, like the similar rocks in the Jackson area, these amphibolite-schists were evidently derived from various forms of more or less basic igneous rocks. In the Sonora area the transformation has generally been complete enough to obliterate the structure of the original rock; but cases were noted in which an altered diorite passed by insensible gradations into an amphibolite-schist. This is well seen on the road between Sonora and Campo Seco, near the eastern edge of the amphibolite-schist area. Although the typical facies of these schists is a dark-green, rather crumbling, fibrous rock, composed chiefly of slender prisms of green hornblende with some visible calcite and biotite, yet the macroscopic and microscopic variation is rather large, indicating their derivation from rocks of extensive range in chemical composition, and probably, also, of considerable original structural variety.

SERPENTINE.

"As in the Jackson area, this rock is regarded as an alteration product of basic gabbros or of ultrabasic igneous rocks of the peridotite family. No evidence was observed, however, of the association between the serpentine and the diabase and amphibolite noted on that sheet. In general the serpentine occurs in broad, well-defined areas of rather irregular shape, or as elongated dike-like masses of very varying width. By far the largest area of serpentine in the district is that lying to the west and south of Chinese Camp, having a width of 4 miles and a length within the boundaries of the sheet of 12 miles.

"The usual rock of this area is a dark-brown serpentine, which forms rather rugged hills of a particularly uninviting aspect, being very sparsely covered with vegetation and weathering to a rusty-red color. Other portions of the mass, particularly near its periphery, weather to the greenish-gray color usual with the serpentines of the Sierra Nevada.

"North of the Crimea House the serpentine is quite schistose, sufficiently so to allow of good observations being taken for dip and strike. In general the rock of this area appears to be completely changed to serpentine. A specimen taken about 1½ miles northeast of the Crimea House showed apparent remnants of a rhombic pyroxene under the microscope, while another specimen, taken from a small outcrop in the serpentine about one-half mile southwest of Chinese Camp, had the mineralogical composition of a wehrlite, and has already been referred to under "Peridotite." Loose pyroxenic bowlders also occur scattered over various portions of the serpentine area. The mapping would indicate that the latter represents an originally intrusive mass of peridotite and related rocks. There is apparently little or no evidence of contact metamorphism about the periphery of the mass, but the exposures are not particularly favorable to its detection.

"Another considerable tract of serpentine is that near Rawhide, in the northwestern portion of the area of the sheet, and which continues southward under the basalt of Table Mountain, down to Sullivans Creek. The rock of this tract is chiefly a dark massive variety, showing glistening cleavage faces of bastite.

"Near the western edge of the tract the serpentine is intimately associated with a rather decomposed gabbro, in a manner strongly suggesting that the gabbro is a portion of the original mass of basic igneous rock from which the serpentine has been derived. A similar close association of serpentine and gabbro occurs on the south side of Table Mountain, about a mile southeast of Rawhide.

"Another area of serpentine extends from a point a little northwest of Coulterville in a northwesterly direction past Pena Blanca to Moccasin Creek. This area is merely a portion of an interrupted and very irregular belt of serpentine which extends from a point 1 mile east of Jacksonville down to the southeast corner of the sheet, near Mount Bullion, and lies generally just east of the main belt of Mariposa slates. The serpentine area west of Rawhide is also directly in the line of this irregular belt, although separated by a longer interval than are any of the other detached portions.

"The serpentine of Pena Blanca resembles that near Rawhide, being dark and massive, with large bastite cleavage faces. Here also it is closely associated with gabbro, a portion of the latter being mapped as a distinct area just east of the serpentine at Pena Blanca.

"This serpentine area divides the otherwise continuous belt of Mariposa slates into two portions about 2 miles northwest of the village of Pena Blanca. The great quartz veins of the Mother lode lie here wholly within the serpentine, and, by their resistance to weathering and erosion, have determined a series of little, sharply pointed spurs or knobs, upon whose summits the white quartz is revealed in conspicuous croppings. Small basic dikes are fairly abundant in the serpentine between Pena Blanca and Moccasin Creek, and were sometimes observed alongside the quartz veins.

"They are generally rather decomposed, but a thin section of one of the fresher specimens showed a granular aggregate of augite, green, partly idiomorphic hornblende, abundant epidote, and some basic plagioclase filling the interstices between the other minerals."

ECONOMIC GEOLOGY.

THE GOLD-QUARTZ VEINS.

The following items about the gold-quartz veins do not indicate all the districts where such veins occur. They are, in fact, found over nearly all the area.

The most important veins of the Sonora area are those of the Mother lode. Many of these have been extensively worked in past times, as, for example, those on the Mariposa estate, to the south of the Merced River. Some of these old mines, particularly the Rawhide and the Cook claims near Coulterville, have been rather recently reopened on an extensive scale. The Mother lode, so well defined at Angels and Carson Hill, may be said to enter the area of the sheet to the west of Tuttletown. The old Patterson mine at Tuttletown may perhaps be regarded as lying to the east of the lode proper. This mine is, however, in the same belt of amphibolite-schist as that in which the famous mines at Angels occur. The Rawhide mine is without doubt on the Mother lode. This lies on the east border of a considerable serpentine area. There is much free gold in the ore, and the green mica, mariposite, is abundant. This mine has produced a large amount in recent years.

To the southeast of the Rawhide, the Alabama, Crystalline, and other quartz veins connect the Rawhide with the Quartz Mountain mines, 2 miles south of Jamestown, where mining is also actively going on. Except one mine northwest of Jacksonville, there are no mines that are being extensively worked until we reach Coulterville. Mining was being actively carried on here in 1895 on several veins. The Red Bank mine, on the north side of the Merced, is the next one of importance to the southeast of Coulterville. On the south side of the Merced the Josephine, Ophir, and Princeton mines, on the Mariposa estate, are now idle, but may be reopened. The above mines are all on the Mother lode belt.

The Golden Gate mine, just southwest of Sonora, is in amphibolite-schist, and the gold occurs in the sulphurets in a gangue of quartz with some calcite.

In mica-schist on the east border of a granitic area just south of Carter post-office is the Eureka Consolidated mine, now producing, and to the south of this, also in schistose slate, is the Seminole.

The New Albany vein, on the east side of the North Tuolumne, southeast of Carter post-office, has a course N. 10° W. and dips E. about 45°. The eroppings are in granite, but a few feet down slate comes in, forming the footwall. The vein matter consists of white quartz and a greenish material, the vein being in places 20 feet thick. Some of the ore shows free gold, iron pyrite, zinc sulphide, and a lead sulphide.

Farther southeast, on the ridge east of the North Tuolumne, are the Hunter and Buchanan mines, not now operating. The vein of the Buchanan mine strikes N. 80° E., or across the strike of the schists. It dips S. 45°.

To the northeast of Horuitos quartz veins are abundant, and some of these have been extensively worked—for example, the Number Nine. The Horseshoe mine, south of Hunters Valley, was being exploited in 1895. There are also numerous pocket mines in this district, and near Chamisal. The Whitlock mines, to the east of the Mount Bullion ridge, are in greenstone, as is also the Yellowstone, about 1 mile west of Bear Valley.

The course of the vein of the Yellowstone is S. 70° W. The ore occurs in the altered greenstone (augite-porphyrite), which is broken up along the vein and recemented with quartz and calcite. A large specimen of the ore, presented to the National Museum by Mr. McDonald, who, in 1893, had charge of the mine, shows spots of free gold at numerous points, associated with white quartz and calcite. According to Mr. Hall, the former owner, in the upper workings much of the gold occurred in calcite.

Pocket mines are very numerous in Greenhorn Mountain ridge, which is made up of the same greenstone (an augitic lava or tuff) as at the Whitlock and Yellowstone.

Large quartz veins, often with a flat dip, are abundant in the greenstone areas of the southwest part of the district, to the west of the Hornitos belt of black sedimentary schists. Most of these are said to be poor in gold. It is also said that most of the gold about Hornitos is of a low grade—that is to say, there is much silver, etc., mixed with it.

The region about the town of Sonora is remarkable as containing a great number of pocket veins, or, in other words, veins in which there are spots rich in gold, with intervening spaces comparatively barren.

The most remarkable pocket mine found is known as the Bonanza. It is in the north part of the town. The ore is found along a diorite dike that cuts the clay-slates. The gold occurs with quartz in the native state and in the form of a telluride. The pockets are said to occur with a certain regularity,[1] and to vary in richness from $4,000 upward. The quartz occurs both on the top and on the bottom, and sometimes in the middle of the dike, which dips at an angle of about 20°.

In the Soulsbyville granite area there are numerous veins that have been exploited. In nearly all cases the ores are rich in sulphides, copper and iron pyrite, pyrrhotite or magnetic iron pyrite, and zinc blende. They usually also contain a galena-like mineral giving blowpipe reactions for both lead and antimony. As a rule, therefore, they need a chlorine or other process to extract the gold.

Accompanying the vein of the Black Oak and the Platt and Gilson mines, there was noted at some points a black schistose material called slate by the miners. The microscope shows that this material is practically an amphibolite-schist and probably represents a sheared diorite or diorite-porphyry that has been intruded as dikes along the vein, similar to the dikes noted under that head. The course of the Black Oak vein is about N. 7° W., dipping about 75° W. The vein is said to be frozen—that is, it is cemented to the granite walls, there being no clay or gouge along the walls.

The Laura and North Star, south of Cherokee, are also in granite, or, more strictly, quartz-diorite. The veins are 2 to 3 feet thick, as noted on the surface, and have free walls. The strike of the veins is N. 54° W.

The Callota is a cross vein at the north end of the Laura.

CINNABAR.

On the steep west slope of the ridge east of Horseshoe Bend is an interesting set of veins, and the writer is indebted to the owner, Mr. C. L. Mast, for specimens of the ore. The country rock is greenstone (an augitic tuff), which is here usually massive in character. There are

[1] Twelfth Ann. Rept. State Mineralogist, p. 301.

two nearly parallel quartz veins, from 1 to 3 feet in width, which strike about N. 40° W. and dip 35° to the NE. The lower of these veins, called the Cabinet, is about 500 feet vertically above the gravel flat on the east side of the bend. The ore of this vein contains copper pyrite and a darker copper sulphide with nearly black streak, probably bornite. Both of these veins are auriferous.

The upper vein is known as the Lookout and is about 200 feet vertically above the Cabinet. Cutting these two white quartz veins at nearly right angles is a vein with approximately vertical dip, known as the Crystal vein, which contains cinnabar along little quartz veinlets which cut the ordinary vein matter. The microscope shows the latter to be made up chiefly of quartz grains with very abundant minute specks of a nearly colorless micaceous mineral with bright interference colors, giving the vein matter in hand specimens a turbid and greenish look. This micaceous mineral is probably talc. In thin section the vein matter resembles a quartzite. The cinnabar is in minute grains and crystals, but is also found in large crystals, some of them with a diameter of two-tenths of an inch.

The occurrence of cinnabar here was noted by Whitney,[1] and later by Becker.[2]

That cinnabar is found in the Blue Wing vein north of Murphys has already been noted. This is likewise referred to by Whitney and Becker. The writer is indebted to Mr. C. L. Mast for the information that cinnabar is also found at Marshs Flat, and for specimens of the ore, which is a decomposed fine-grained greenstone on which are distinct stains of cinnabar. It is not likely that any of these deposits of quicksilver ore will prove of economic value.

MARIPOSITE.

The green micaceous mineral so characteristic of the Mother lode in Tuolumne and Mariposa counties, and which was called mariposite by Silliman, occurs abundantly at the Josephine mine, near Bear Valley. Several specimens of this were obtained in 1893, and submitted to Prof. F. W. Clarke for analysis. Thin sections of the material were made, and these show that the mineral is micaceous, nearly colorless or slightly greenish with brilliant polarizing colors, resembling talc or sericite. There appears to be no perceptible pleochroism. The mineral is in the form of fibers and minute irregular foils with ragged edges, and extinguishes nearly or quite parallel to the longer axis of the fibers. Macroscopically, it is not all green, some of it being nearly white. Two analyses by Dr. Hillebrand are appended, one of the green and the other of the white mineral.

[1] Geology of California, Vol. I, p. 230.

[2] Quicksilver deposits of the Pacific Slope: Mon. U. S. Geol. Survey, Vol. XIII, 1888, p. 383.

Analyses of mariposite (438 S. N.).

	Green.	White.	Chrome muscovite.
	Per cent.	*Per cent.*	*Per cent.*
SiO_2	55.35	56.79	46.17
TiO_2	.18	25.29	29.71
Al_2O_3	25.62		
Cr_2O_3	.18	None.	3.51
Fe_2O_3	.63	1.59	2.03
FeO	.92		
CaO	.07	.07	....
MgO	3.25	3.29	2.28
K_2O	9.29	8.92	10.40
$(Li\,Na)_2O$ *a*	.12	*b* .17	....
H_2O *c*	4.52	4.72	5.42
	100.13	100.84	99.52

a A very strong lithium reaction. *b* Containing some K_2O. *c* No water given off below 300 C.

The thin sections show that there is carbonate, probably chiefly dolomite, mixed with the mariposite. This with some carbonate of iron was extracted with acetic acid followed by warm dilute HCl, the mariposite substance remaining unattacked. Dr. Hillebrand calls attention to the resemblance of the mineral in composition to pinite, and states that no definite formula is deducible. He determined the specific gravity of the green mineral to be 2.817 at 29.5° C., and that of the white mineral to be 2.787 at 28.5° C. The occurrence of chromium in the green variety and not in the white suggests that to be the cause of the green color.

The analysis of the chrome muscovite is taken from Dana's Manual of Mineralogy, 1892, p. 619. The locality is Syersk, and the mica is said to be green. Some of the analyses of pinite given by Dana do not differ much from the analysis of the chrome muscovite, but they do not indicate the presence of any chromium sesquioxide.

Associated with mariposite at the Josephine mine and at Quartz Mountain in Tuolumne County, as well as many other points along the Mother lode, is a white mineral which at some points appears to form veins in the mariposite. This is probably the mineral called ankerite by Silliman. An examination of this material by Dr. Hillebrand shows that it is ordinary dolomite mixed with quartz, and not ankerite. In the Josephine mine, erythrite, a hydrous arsenate of cobalt, forms on surfaces and in seams of the rock adjoining the vein. According to the State mineralogist[1] of California, danaite (cobaltic arsenic sulphide) is also found in the vein matter.

[1] Twelfth Ann. Report, p. 175.

THE OAKDALE AREA.

This area, lying immediately west of the Sonora district, has not as yet been topographically mapped. The Auriferous slate series and the interbedded old lavas form the larger part of the northeast portion of the area, the main part of which lies in the San Joaquin Valley. These older rocks may be entirely Juratrias in age. Texas ranch, where Mr. C. D. Voy, and later others,[1] collected fossils characteristic of the Mariposa formation, is on the west side of a branch of Angels Creek to the north of the Sonora and Copperopolis stage road. The slates in which the fossils occur are part of the same belt of the Mariposa formation shown on the Sonora map along Woods Creek, where it lies just west of the Mother lode.

The belt of clay-slates supposed to belong to the Mariposa formation that crosses the Merced River at Merced Falls and the Tuolumne River at La Grange strikes into the area of the Oakdale sheet, but has not been seen at any point in that area. These slates are probably concealed under the Tertiary and later sediments of the San Joaquin Valley.

West of Telegraph City, by the old stage road to Stockton, where a prominent point of the ridge south of Telegraph City known as Hog Hill bears about S. 66° E., is an area of a granitoid rock (No. 71 Calaveras). The microscope shows this to be a quartz-hornblende-diorite containing a little brown mica and iron ore. In contact with the granitic area was collected a green schist which strikes nearly north and south and dips 65°. This is composed of recrystallized green hornblende, patches of a brown chloritic (?) mineral showing a spherulitic structure, and gray patches made up chiefly of a quartz-feldspar mosaic. Iron oxide is abundant.

Whitney[2] notes a granitic area which he considers responsible for the altered condition of the rocks near Quail Hill. The altered rock referred to is called "calico rock," which appears to be a decomposed porphyry showing brilliant colors, and presumably in a zone of solfataric action. This "calico rock" was at one time supposed to be rich in gold. Prof. Benjamin Silliman visited Quail Hill about 1867 and published some notes concerning it.[3]

Near Telegraph City some copper deposits have been mined, and at Copperopolis the Reed copper lode has produced a large amount. The ore is copper pyrite and is said to contain some gold. West of Telegraph City there are large amounts of a rusty iron-stained sandstone of Tertiary age. In addition to Whitney and Silliman, Goodyear[4] gives some brief notes on the geology of Copperopolis, Quail Hill, and vicinity.

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[1] See Fourteenth Ann. Rept. U.S. Geol. Survey, Part II, 1894, pp. 453-454.

[2] Auriferous Gravels, p. 122.

[3] Proc. California Acad. Sci., Vol. III, 1867, pp. 387-399.

[4] Am. Jour. Sci., Vol. XL, 1868, pp. 92-95, and Proc. California Acad. Sci., Vol. III, pp. 349-351.

Large areas of the black basaltic-looking lava of the Tuolumne Table Mountain flow are to be seen north and south of the Stanislaus to the east of Knights Ferry.

In the northeast part of the district are considerable bodies of serpentine. The pre-Cretaceous rocks are, however, chiefly lavas and tuffs. Those of the northeast section are more basic and contain more augite than elsewhere in the district. At Knights Ferry bridge is a granitoid rock containing metasilicates in very small amount (No. 516 S. N.). The feldspars are twinned on the albite law, and are either albite or andesine. North of Knights Ferry is a very large area of an acid lava with porphyritic quartzes. It is, in fact, an extension of the quartz-porphyrite area of the Gopher Ridge (Jackson sheet).

THE MERCED-MARIPOSA DISTRICT.

The area so designated covers that part of Mariposa and Madera counties which will, when topographically mapped, form two atlas sheets lying just south of the Sonora and Yosemite districts.

HOG-WALLOW MOUNDS.

Along the east side of the San Joaquin and Sacramento valleys, chiefly in the area of red soil and gravel called on the geologic maps early Pleistocene, there are often to be noted little mounds between which are depressions in some of which water stands after a rain, showing that the depressions are little basins without any outlet. The little mounds are not confined to the level stretches, but are found on the slopes of the first low foothills. This is illustrated by Pl. XXXIII, which is from a photograph taken by the road from Snelling to Merced. The tops of the plateau-like ridges south of Snelling appear likewise to be dotted with the little mounds. They are usually less than 2 feet in elevation, often less than 1 foot, and have a diameter of from 4 to 10 feet (approximately). Where sections of them had been made along the new cuts in the road, it was evident that they are made of the same red soil mixed with pebbles that forms the intervening spaces. In the depressions there are often a number of larger pebbles. A similar observation as to kind of material composing the mounds was made by the road from Hornitos to Merced southwest of Indian Gulch. The little mounds are abundant on the hills south of Indian Gulch. These hills are composed of pre-Cretaceous schistose rocks, and the little mounds in this case appear to be made of the soil formed directly from the underlying rock.

On the andesite-breccia area that covers the top of the ridge west of Corral Creek, in the northeast part of the Sonora area, may be noted little mounds about 3 feet in height and 15 feet in width. These are composed of fine material without any of the coarse rubble of the breccia. It is not likely that these have an origin similar to those in the lower foothills and on the plains. To one who has seen the little mounds made by ground squirrels in the Coast Ranges the resemblance of the mounds shown in the illustration to the squirrel mounds will be at once apparent. In many cases squirrels are now living in these little mounds of the plains region and foothills of the Sierra Nevada, but many of them show no trace of former burrows. The surface of the mounds is sometimes quite bare, but usually it supports a growth of grass of the same character and about the same in amount as on the intervening spaces, as may be seen in the illustration. There are no shrubs in the middle of the mounds and there is no evidence that there ever were any, around which the wind might have gradually collected soil. Moreover, as stated above, the mounds in the plains region are made up of the same sort of material as that forming the intervening spaces, neither coarser nor finer, with the exception of occasional groups of large pebbles, heretofore noted, which lie on the surface.

While the evidence is not sufficient to warrant assigning to squirrels or other rodents the making of the hillocks, it is thought that this origin should be considered. That little hillocks are made by the drifting of sand about a clump of grass or brush has been often noted. Such little hillocks may be seen along the Central Pacific Railroad near the station of Desert, Nevada. Such mounds are also described by Dr. G. W. Barnes[1] as being found in San Diego County, and that writer ascribes to the agency of vegetation and wind erosion the formation of mounds which appear to be similar to those here referred to, while recognizing that burrowing animals assist in enlarging the mounds in some cases.

Professor Whitney, who published the first notice of the mounds which the writer has noted, states[2] that the "hard clayey soil south of Kings River is thrown up into alternate hillocks and hollows, popularly known as 'hog wallows,' the origin of which is not easy to explain. They resemble the hillocks left by the gradual decay of trees uprooted by the wind in our eastern forests, and the depressions between them contain water in the rainy season."

Prof. Joseph Le Conte describes the so-called prairie mounds of Washington, and refers likewise to the "hog wallows" of California. Professor Le Conte states[3]—

> That his observations in eastern Oregon, where they occur in every variety of form, size, and regularity, and in California, convince him that they are the result of surface erosion under peculiar conditions; these conditions being a bare country and a drift soil more movable above and less movable below. Erosion removes the finer top soil, leaving it, however, in spots. The process once commenced, weeds, shrubs, and ferns take possession of these spots as the better soil, or sometimes as the drier soil, and hold them, and by their roots retard the erosion there. In some cases a departing vegetation—a vegetation gradually destroyed by an increasing dryness of climate—is an important condition.
>
> Certain it is that in all the treeless regions of California and Oregon that have not been touched by the plow, the same phenomenon may be observed to a less extent.

[1] The hillocks or mound formations of San Diego, Cal.: Am. Naturalist, 1879, p. 565.

[2] Geology of California, Vol. I, p. 367

[3] Abstract in Proc. California Acad. Sci., Vol. V, p. 219.

HOG-WALLOW MOUNDS.

In California they are called "hog wallows." The hog wallows of California may be traced by insensible gradations into the larger mounds of eastern Oregon, and these, in their turn, into the more perfect mounds of Mound Prairie; they are all evidently due to the same cause. If the mounds of Mound Prairie were a unique phenomenon, we might resort to exceptional causes; but a phenomenon so widespread must be due to a widespread agent.

Some information as to the agricultural value of the "hog-wallow" lands will be found in a report by Prof. E. A. Hilgard on the physical geography of the State of California.[1]

As a rule, where seen by the writer, these lands are uncultivated. Their hummocky nature makes the plowing of them a difficult matter, and the soil as a rule is poor.

TERTIARY SEDIMENTS.

The first consolidated rock seen in place by the road from Madera to Daultons is a coarse reddish sandstone, with the same pearly kaolin-like scales as are found so abundantly in the sandstone of the Ione formation in the Jackson area. Farther northeast, resting on mica-andalusite-schist, some sandstone was noted consisting of angular quartz grains embedded in a whitish, opaque, clay-like matrix very similar to some of the Ione sandstone northeast of Camanche and at the base of the hill west of Jones Butte, near Ione.

Forming a set of low, level-topped buttes along the edge of the foothills to the southeast of Merced Falls is a sandstone formation very similar to that which just south of Merced Falls contains Eocene fossils. They are therefore presumed also to be of Eocene age. The sandstone of these hills is beautifully exposed. It was carefully examined at many points for fossils, but none were found.

In a paper on the Auriferous Gravels,[2] attention was called to an interesting locality of vertebrate remains described by Professor Whitney as being on a dry creek tributary to Bear Creek near the line of Mariposa and Merced counties. A search was made for this locality, but no evidence of such remains was found. Professor Whitney later informed the writer that he himself had investigated this locality and had been unable to find it.

TERTIARY VOLCANIC ROCKS.

Along the east side of the valley to the south of the Merced River is a plateau, the upper layers of which, where examined, are composed of andesitic detritus mixed with ordinary sand. Some of the white underlying material may be of rhyolitic origin; at any rate the white material at the edge of the plains just west of Daultons in Madera County is rhyolite. Some information concerning the lava flows that form the top of the Millerton Table Mountain may be found in Blake's report.[3]

[1] Tenth Census, Vol. VI, Part II, pp. 665-731, bottom pagination.
[2] Am. Geologist, Vol. XV, p. 371.
[3] Pacific Railroad Reports, Vol. V.

THE AURIFEROUS SLATE SERIES.

To the student of the pre-Cretaceous rocks the Merced-Mariposa region is one of more than usual interest. The Auriferous slate series of the Gold Belt practically terminates in this region, being cut off by large granitic areas. The granite forms a large area south of the town of Mariposa, and it is in this region that the Mariposa slates terminate, abutting directly against the granite. The area of greenstones which forms Mount Bullion and the ridge trending southeast from there extends as a narrow tongue for an unknown distance southeast. It was observed by the writer on the North Fork of the Fresno River east of Grub Gulch, where the greenstones have been converted into amphibolite-schist. There is also at this point some mica-schist. In the line of strike of this belt of amphibolite-schist occur the mining camps of Fine Gold and Coarse Gold, which are said to be in or near schistose rocks, probably a continuation of the belt here noted.

On the southwest part of the Sonora geologic map may be noted two belts of sedimentary rock, an eastern one, supposed to be of Carboniferous age, which crosses the Merced River west of Horseshoe Bend, and a supposed Jurassic belt crossing the same river at Merced Falls. A belt of greenstone tuffs and schists separates the two slate belts above noted. These greenstones give out a little to the southeast of the Tres Cerritos, which are about 2 miles southwest of Indian Gulch, so that along Owens Creek the two belts of slates come together. This creek, rising in Cathay Valley and flowing southwesterly, makes a fine section of the series. The Mariposa slates at the mouth of the canyon of Owens Creek, or where it enters into the plains of the San Joaquin Valley, have been metamorphosed into chiastolite-schist by an intrusive granitoid rock. After passing through this metamorphic belt, going northeast, the slates are quite unaltered for a distance of perhaps 3 or 4 miles until the granitic area of Cathay Valley is approached, when another zone of contact-metamorphic rocks may be noted.

The belt of chiastolite-schist noted as lying to the southwest of the Tres Cerritos and extending thence to Owens Creek pretty certainly continues southeast to the Chowchilla River, for in that vicinity there is a wide belt of these schists which was followed by the writer as far south as the San Joaquin River, where it leaves the foothills and enters on the plains of San Joaquin. The belt of schist at Daultons is 2 miles wide, but on the Chowchilla River it has a width of 4 or more miles, the entire series being more or less thoroughly crystalline. In it are numerous dikes of a hornblende-diabase. In the neighborhood of Daultons, as was first noted by Blake,[1] the square prisms of chiastolite, having a length sometimes of 2 inches, lie scattered over the ground and also form parts of a conglomerate of Tertiary age that

[1] Pacific Railroad Reports, Vol. V.

rests on the older rocks at points along the foothills. In the vicinity of the Chowchilla River there are numerous lenses of quartz in the chiastolite-schists, which, having resisted the weathering better than the surrounding rocks, now form the white tips of little conical buttes. Southwest of Green Mountain these buttes are numerous, forming a peculiar landscape.

The Tres Cerritos, southwest of Indian Gulch, are three sharp buttes which, like the little cones just mentioned, owe their prominence to the silicified character of the rock of which they are composed. The original material of the buttes appears to have been diabase and greenstone slate with some clay-slate, and has been subjected to silicification, and is apparently also in a zone of solfataric action. The southeast butte, which was examined with the most care, is composed chiefly of greenstone-schist with layers of vein quartz, associated with which is pyrophyllite in considerable masses, crystallized in beautiful stellate forms. The much decomposed and rusty schists in the creek at its base strike about 60° west of north and dip at an angle of 80°, and at a point about due west of the butte they are covered with an efflorescence of hydrated sodium and magnesium sulphates, with a little chloride, and with calcium sulphate in the interior, as determined by Dr. Stokes from samples brought from there.

Forming part of the same altered mass as that in which the pyrophyllite occurs is a light-colored, medium-grained quartzite-like rock which the microscope shows to be made up chiefly of grains of quartz and a positive uniaxial mineral of greater relief than the quartz, extinguishing parallel to the cleavage and having bright interference colors. Dr. Hillebrand made a chemical examination of this rock and found that it gives off water on heating, and also SO_3 (SO_2 also?). H_2SO_4 decomposes it, and the filtrate shows much alumina and alkali, both sodium and potassium. The mineral is therefore a sulphate of alumina and alkali, as there is practically nothing in the rock but quartz and the sulphate. Its chemical composition and optical properties make it probable that the mineral is alunite, which is uniaxial and positive. Since alunite occurs in solfataric zones, its presence with the pyrophyllite at the Tres Cerritos is not strange. It has not been previously found in California, so far as known to the writer. Except in the age and exact nature of the original rocks concerned, the Tres Cerritos quartz-alunite rock appears to be very similar to a quartz-alunite rock forming Democrat Hill and the rugged crest of Mount Robinson in the Rosita Hills,[1] Colorado.

The zone of contact-metamorphic schists noted on Owens Creek in the Mariposa slates is continued northwest and is crossed by the road from Indian Gulch to Merced a mile southwest of the Tres Cerritos. The andalusite crystals are beautifully developed and form typical specimens of the contact-metamorphic rock.

[1] Whitman Cross: Proc. Colorado Sci. Soc., 1890, p. 277.

On account of the striking character of the contact phenomena at many points in the district, an examination was made of one locality, which is herewith appended under a special heading.

CONTACT METAMORPHISM.

By contact metamorphism is meant those alterations in a rock mass that take place along the border of an intrusive rock in consequence of the heat and mineralizing solutions whose origin is due to the intrusive rock. In the metamorphic zone new minerals have been formed, chiefly by the recrystallization of the material of the rock that is metamorphosed.

This phenomenon has been noted in many parts of the world, and careful investigations have shown beyond all reasonable doubt that the formation of these minerals took place after the intrusion of the igneous magma and as a result of it.

The investigations of Hawes[1] have, indeed, made it certain that in one instance there has been an addition of boric acid to the schists from the mineralizing solutions, resulting in the formation of abundant tourmalines in the zone nearest the granite. Rosenbusch,[2] in a very thorough investigation of contact phenomena, however, found that at the locality which he studied the new minerals developed were almost wholly due to the recrystallization of the material of the schists.

In the descriptions of the hornblende series of the Bidwell Bar area the recrystallization of the uralitic greenstones of the Forbestown ridge was indicated as the result of contact metamorphism. Contact-metamorphic zones have been also noted in the clay-slates southwest of Indian Gulch, at Burns Creek where it enters the San Joaquin Valley, at the head of Owens Creek southwest of Cathay Valley, and in the broad belt of mica and chiastolite schist extending south from the Chowchilla River to the San Joaquin. It is quite probable that in no other part of the world are contact phenomena more plainly exhibited or so easily studied as in Mariposa County. The rocks are, as a rule, finely exposed, particularly along the creeks, and on the ridges south of Owens Creek as well. Another locality where contact metamorphism is well displayed is in Yaqui Gulch, about 2 miles southwest of the town of Mariposa. These schists are part of a zone of contact-metamorphic rocks at the south end of a long belt of Mariposa slates which extend from Colfax, in Placer County, to Yaqui Gulch, a distance of about 130 miles. To the west of Placerville this belt of slates is in contact with an area of fine-grained porphyritic granite, and, according to Mr. W. Lindgren, does not seem to be greatly altered; but the contact was examined hastily. Only at its south end is this slate belt in contact with any large area of an intrusive granular rock of a granitoid nature, and at no other point are the slates so highly altered.

[1] Am. Jour. Sci., Vol. XXI, p. 21.
[2] Die Steiger-Schiefer, Strasburg, 1877.

The area is not, in this vicinity at least, connected with the great granite mass of the Sierra Nevada, a narrow projecting tongue of greenstone and mica-schists separating it; but it is of large size and extends at least as far southeast as the San Joaquin River, a distance of 35 miles, having an average width of 12 or more miles. This granitic rock is not at the contact a true granite, as may be seen from the analysis, and, indeed, this is true of most of the area. The fine-grained granite from the quarry at Raymond is more nearly a normal granite in composition, but the writer is unable to say whether this is a fair average of the granite of the interior of the area. The analysis of No. 369 is from the west edge of the area on the Chowchilla River, and its chemical composition may differ from that of the average of the area as a result of magma differentiation, which is in some way related to the contact of the schist series. It is not thought, however, that there is any relation between this basic facies of the area and endomorphic contact metamorphism; that is to say, it is not thought that there has been any transfer, at least of any of the constituents represented in the partial analyses, from the schist mass to the granite.

Analyses of the Raymond granite area.

	No. 369, Chowchilla River.	No. 372, Raymond quarry.
	Per cent.	*Per cent.*
Silica	62.62	73.54
Lime	5.49	2.55
Potassa	1.76	1.89
Soda	3.49	4.66

In Yaqui Gulch, near the eruptive rock, the Mariposa schists have been irregularly displaced, and their relation to the granite is not a perfectly simple one, so that the study of the details of the metamorphism is not so satisfactory as it would otherwise be.

The general course of the line of contact between the granite and the schists is very nearly east and west. The rocks at or near the granite are much obscured by soil. The specimen collected nearest to the granite is a rather coarse-grained andalusite-hornfels (No. 852 S. N.). This was taken on the east side of Yaqui Gulch (in reality at the mouth of the gulch proper, or where it opens into the valley of Agua Fria Creek), at a point about 2,500 feet north of the main contact of the granite area. This hornfels is presumed to have been originally a sandstone. The expression "main granite contact" is used for the reason that a small mass of granite, doubtless an apophysis of the main area, occurs on the west side of the stream bed, not far from opposite to the point where specimen 852 was collected. The contact of the granite and the schists is probably not a vertical one. Moreover, the granite area just north of Yaqui Creek swerves to the northwest.

About 1,300 feet upstream from No. 852, or about 3,800 feet from the main granite area, the schists are well exposed in the bed of the stream. Here was collected a knotted mica-schist, No. 432. The strike of the schistosity is here about N. 16° E., the dip being 70° to the east. The planes of schistosity and bedding here coincide. The beds thus lie nearly at right angles to the course of the main granite contact; a few feet south of this point, however, the schists dip irregularly and are at points contorted.

At a point perhaps 500 feet north of No. 432 the strike of the schists is about the same, being N. 20° E., but the dip is in the opposite direction, or to the west, the angle being 60° from horizontal.

A few hundred feet still farther north, or approximately 5,000 feet from the main granite contact, there is a marked change in the strike of the schists, their course being about N. 30° W., the average dip being 60° to the east. This may be said to be the normal strike and dip of the slate belt, although local variations are common. The dip is, however, nearly always more than 50°, and often vertical, and the strike is almost always between north and northwest.

Specimen 433 is a micaceous schist, and was taken at about the point where the general strike of the beds changes to the west of north. Chiastolite-schist was found at various points within a distance of about 1,200 feet in that part of the Yaqui Gulch where the strike of the beds is to the east of north, or in a zone from 3,800 to 5,000 feet from the main granite area. The chiastolite-schist occurs in layers interbedded with mica-schists like No. 433. Often these layers are but 2 to 6 inches in thickness. It is thus evident that their formation depends largely on the original composition of the layers. Those containing the larger percentage of argillaceous matter appear to develop into chiastolite-schists, and the more sandy layers into micaceous schists. This would of course be expected of a mineral like chiastolite, which is a nearly pure silicate of alumina, to which is added certain impurities, which are usually aggregated at the center or arranged more or less zonally, and often also in diagonal lines extending to the prism edges. Some of the chiastolite-schist collected near specimen 432 contains distinct impressions of *Aucella erringtoni*[1] or one of the closely allied varieties, described by Professor Hyatt. This fossil is characteristic of the Mariposa slates, which are said to be of Jurassic age by Professor Hyatt, Professor Smith, of Stanford University, and others, confirming the original determination by Meek. It is thus evident that the granitoid rocks which have effected the metamorphism of the clay-slates are of late Jurassic or post-Jurassic age.

More than 5,000 feet away from the granite the Mariposa beds are no longer greatly metamorphosed. They are no longer schists, but clay-slates, though they still show some effects of the metamorphic action of the granite by the presence of very abundant minute prisms. Specimen

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[1] This discovery was made by James Storrs.

No. 855, showing these prisms, was taken from near the head of Yaqui Gulch more than a mile from the granite. Some of the clay-slates at this point, however, showed no prisms whatever, even when examined microscopically. The metamorphic action of the igneous mass appears to have ceased at a distance of perhaps 6,500 feet from the contact. In regard to the distances here given, it should be stated that they are all approximate. Some of them were measured by pacing, others only estimated. A contour map has not as yet been made of this region, which lies directly south of the Sonora area.

Fig. B of Pl. XXXV represents a hand specimen of the chiastolite-schist in which the chiastolite prisms are weathered to a light color, and hence are in strong contrast with the dark-brown matrix in which they lie. This was obtained at the same point as 431 S. N., which differs from the specimen figured merely in being fresh.

Chiastolite-schist (No. 431 S. N.).

Locality: Yaqui Gulch, 2 miles southwest of the town of Mariposa and about 3,800 feet north of the main granite contact.

Macroscopically, when fresh, a hard, black, fine-grained schistose rock, with very abundant minute points with a silvery reflection and slender prisms which are square in cross section. These prisms are sometimes an inch in length, but usually shorter. In weathered specimens a dark center can be seen in some of the cross sections of the prisms.

Microscopically, when seen without the analyzer, the chiastolite-schist shows a fine-grained, dark groundmass composed of minute clear grains, many of them rounded, abundant minute black particles, and reddish-brown mica scales arranged in more or less nearly parallel lines, giving the schistose structure to the rock. In this groundmass are long, clear prisms which are square in cross section, and minute clear prisms which are nearly of a size, having a width of 2/100 mm. and a length of about 2/10 mm. Many of these lie at an angle to the plane of schistosity, suggesting their formation after the schistose structure of the rock had been formed. The large prisms with square cross sections are chiastolite, and are from 1 to 2 mm. in diameter. The dark cross which distinguishes chiastolite from andalusite is feebly developed in many of the prisms, and consists of lines of minute black granules extending from the center to the prism edges, bisecting the prism angles. The minute black particles are presumed to be carbonaceous. By reflected light they show a metallic luster on some surfaces, so that they are probably graphite. Some of the rock was powdered and washed. A black dust that collected on the water was found to be consumed when placed on a platinum spatula in a flame at a high temperature. The powder is therefore carbon, and without doubt represents the black particles seen under the microscope. The minute clear prisms seen in natural light probably represent the silvery points observed macroscopically. These are sillimanite. With crossed nicols they extinguish parallel to the direction of elongation and show interference colors, reaching to blue of the second order. The axis of least elasticity was determined to lie parallel to the vertical axis or the direction of elongation of the prism. This, with the brighter interference colors, is an easy and accurate method of distinguishing sillimanite from andalusite or chiastolite. The clear cross sections of the chiastolite crystals show the two prismatic cleavages intersected nearly at right angles. In the cross sections the extinction is diagonal, bisecting the prism angles and the intersections of the cleavage lines. In longitudinal sections the two cleavages are indicated by parallel lines and the extinction is parallel to the cleavage. The outer edge of even the freshest chiastolite crystals is altered to a fibrous colorless aggregate, which, according to Rosenbusch, may be a mixture of sericite and kaolin, and occasionally irregular cracks extending into the crystals are sometimes filled with this same decomposed product. The fibers of the decomposition rim usually stand approximately normal to the prism planes. The particles of the groundmass to a certain extent exhibit a tendency to flow around the chiastolite crystals—that is to say, they are arranged in lines roughly parallel to the sides of the prism. This is best seen in the cross sections, and may be taken to indicate that the schists were in a plastic condition after the crystals were formed. A few minute veinlets cut the section, filled with a clear mineral in little grains, which is apparently quartz. The powdered rock was tested for magnetite, but only a few grains were found.

No. 433 S. N., taken in Yaqui Gulch about 5,000 feet from the granite contact, shows macroscopically very abundant minute silvery points. When examined by the microscope these silvery points proved to be minute prisms of both sillimanite and andalusite, the sillimanite being identical with the smaller prisms developed in the chiastolite-schist, No. 431. There are also abundant minute scales of a reddish brown biotite, often grouped about the sillimanite prisms.

No. 434 S. N., taken about 6,000 feet from the granite contact, is a black clay-slate, with abundant minute dark prisms. These prisms undoubtedly represent original andalusite or sillimanite, but are all altered to a fibrous aggregate similar to that surrounding the fresh chiastolite prisms in No. 431.

No. 855 S. N., taken in Yaqui Gulch about 6,500 feet from the granite contact, is a fissile clay-slate similar to No. 434. Microscopically the rock presents a confused appearance, there being no definite crystals of any kind whatsoever developed. The minute needles seen microscopically are, in all cases examined, altered to a fibrous aggregate. Abundantly disseminated through the rock is a very finely divided black pigment, presumably carbonaceous. Some of the clay-slates taken at the same point as No. 855 show no prisms whatsoever.

Where the granite is in contact with the augite-tuff series along Stockton north of Mormon Bar, they show the effects of contact-metamorphism in the formation of acicular hornblende which can be noted with a hand lens, and a narrow tongue of greenstone west of Sevastopol has been altered into a gneissoidal hornblendic rock, very similar to the recrystallized greenstone No. 518, of the Forbestown ridge in the Bidwell Bar area.

On the Chowchilla River, at the contact with the granite area of Raymond and Mormon Bar, the sedimentary rock looks so gneissoidal that a specimen of it was collected to determine what alteration it had undergone, or, if possible, whether it was not a gneiss formed from the detritus from the granite, in which case, of course, the granite would be older than the gneissoid rock. The evidence, however, is in the other direction. The granite, or more correctly the quartz-mica-diorite, is represented by No. 369 S. N., analysis of which is given below. The rock contains plagioclase, quartz, biotite, some hornblende, and orthoclase, and is not noticeably different from quartz-mica-diorites of other portions of the range.

The gneissoidal schist (No. 368 S. N.) is largely quartz with much turbid feldspar and with both biotite and muscovite. An analysis of this also is given. Directly west of the gneissoidal quartz-schist is a belt of hard mica-schist containing little rose-colored garnets, immediately west of which is the mica-andalusite-schist belt in which occur the Buchanan and Ne Plus Ultra mines. A specimen of the mica-andalusite-schist (No. 365 S. N.), taken 500 feet west of the granite contact, was also analyzed. It will be noted that both No. 368 and No. 365 contain carbon, probably in the form of graphite.

Analyses of granites and schists.

	No. 369 S. N., quartz-mica-diorite.	Schists.		No. 399 S. N., micropegmatite.	No. 400 S. N., hornfels.
		No. 368 S. N.	No. 365 S. N.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	62.62	70.40	64.28	73.18	68.27
TiO_2	.55	.51	.65	.25	.57
Al_2O_3	17.51	14.70	17.28	13.66	14.03
Fe_2O_3	.49	.65	1.10	.21	.46
FeO	4.06	*a*2.57	*a*5.34	2.24	4.68
MnO	.05	.08	.09	.07	.04
CaO	5.49	1.63	1.19	2.10	3.89
SrO	Trace.	Trace.	Trace.	Trace.	Trace.
BaO	Trace.	.09	.10	.10	.08
MgO	2.84	1.47	2.57	.93	2.23
K_2O	1.76	3.46	2.93	2.72	2.35
N_2O	3.49	3.17	.91	3.70	2.29
Li_2O	Trace.	Trace.	Strong trace.	Trace.	Trace.
H_2O below 110° C	.22	.19	.20	.10	.08
H_2O above 110° C	.92	.91	2.72	.57	.98
P_2O_5	.12	.05	.27	.09	.21
CO_2	....	....	....	.17	....
Carbon from organic matter—Graphite?	....	.15	.43	....	....
Total	100.12	100.03	100.06	100.09	100.16

a Dr. Hillebrand, who made the above analyses, states that the FeO in No. 365 and No. 368 is perhaps too high, owing to the reducing action of carbonaceous matter on solution with HFl and H_2SO_4, and titration by $K MnO_4$. The Fe_2O_3 in that case would be correspondingly low.

The fine-grained soda-granite referred to later is finely exposed in the bed of Agua Fria Creek 3 miles south of Mount Bullion post-office. At this point it is in contact with the Mariposa formation, which here forms the east bank of the stream. The fine-grained granite is here a micropegmatite containing brown mica, and is more basic than in the interior of the area, where the soda content is much higher.

No. 399 in the table of analyses given above represents the micropegmatite, and the soda-granite from the interior of the area is represented by an analysis (No. 413) given in the table of the granite family in Chapter VI. The contact of the fine-grained granite with the Mariposa formation is sharp, but the Mariposa beds are not highly altered. However, they are rendered hard and flinty, and contain reddish-brown mica. The clastic nature of the rock is very evident in sections. At the contact of the two rocks a green dike (No. 403) cuts both the fine granite and the Mariposa beds. This dike appears to be a variolite. In the center of it is a band of spherulites, which shows plainly on the weathered rock. The microscope shows that these spherulites are composed of radial or brush-like feldspar with numerous minute specks of mica. At the edges of the dike the spherulitic structure does not seem to be developed.

Although not greatly altered near the contact, the Mariposa rocks are so flinty in texture that they may be called hornfels. They are light-gray in color, and their sedimentary nature is not certainly evident in the field. About one-fourth mile above the point where the specimens just noted were collected, Agua Fria Creek, as one goes upstream, bends sharply to the right in an easterly direction, cutting across the strike of the Mariposa slates. Near the contact the light-gray hornfels dips about 35° to the northeast. A few hundred feet to the east the dip is about 45°, and just west of the old mining camp of Agua Fria, now represented only by the ruins of a few stone houses, the dip is about 70°. The strike of the beds in the entire section is about N. 40° W. The former town of Agua Fria was located on Agua Fria Creek, about 2 miles south of Mount Bullion post-office. An analysis of the hornfels from the contact of the fine-grained granite and the Mariposa beds on Agua Fria Creek (No. 400 S. N.) is given in the above table. The comparatively unaltered condition of this rock at the contact contrasts sharply with the highly altered condition of the hornfels and chiastolite-schists in Yaqui Gulch, about 1½ miles to the southeast. The difference is to be explained chiefly by the character of the two granites, one being a thoroughly granular rock and the other a micropegmatite, which may be presumed to have crystallized under different conditions from the Yaqui Gulch granitoid rock, resulting in less intense mineralizing solutions being formed.

THE GRANULAR IGNEOUS ROCKS.

SODA-GRANITE.

To the southwest of the town of Mariposa, in the drainage of Agua Fria Creek, is a large mass of a white, fine-grained, granitic rock, which is probably of a different age from the coarser quartz-mica-diorite or granodiorite mass that joins it on the east. Analyses of two samples of this granite (Nos. 398 and 413 S. N.) may be found in the table of granite analyses, which show that it is a granite rich in soda-feldspar and of very different composition from the quartz-mica-diorite. The contact between the two granitoid rocks was examined with some care on Agua Fria Creek, but the evidence was not conclusive as to their relative age. To the west of the soda-granite here noted are considerable masses of a basic igneous rock, chiefly a diabase, and along the contact, in and southeast of Cathay Valley, a contact breccia has been formed, making a zone a mile or more in width, composed of fragments of the diabase, cemented by a matrix of the soda-granite. No such wide zone of contact breccia has been noted by the writer at any other point in the range.

QUARTZ-MICA-DIORITE.

Nearly all the so-called granite in southern Mariposa and Madera counties is, as indicated under contact metamorphism, of the granodiorite or quartz-mica diorite type. This is true of at least a portion of the area lying south of the town of Mariposa and of the larger area in the Mariposa district, which is part of the same area as that of Yosemite Valley. A complete analysis of a quartz-mica-diorite (No. 369 S. N.) from the Chowchilla River will be found in the table of analyses of the quartz-diorite family and under the heading "Contact metamorphism."

DIABASE.

The same diabase that forms numerous dikes and areas in the schists northeast of Hornitos is found in still larger areas, particularly on Schultz Mountain and west of Cathay Valley. This is the most typical diabase known to the writer in the Sierra Nevada. It is a dark, heavy rock, of a diabase-granular or ophitic structure, and made up of labradorite and other feldspars, iron ore, and sometimes biotite. It is later than the slates and greenstone schists south and northeast of Hornitos, for it cuts them in dikes. It is earlier than at least the fine-grained soda-granulite, for it is intruded by that rock. The diabase-granular structure of one of them (No. 415 S. N.) is represented by photomicrograph Pl. XLV, B. Dikes of this rock were noted by Reyer[1] in the neighborhood of Hornitos and called by him dark diorite, which, indeed, it is at times, according to the old definition of diorite, for it sometimes contains brown hornblende to the exclusion of augite.

South of Cathay Valley may be noted a prominent cone known as Cathay Hill. About 2,000 feet southeast of Cathay Hill, in a direction S. 54° E., is another similar cone, perhaps 50 feet lower. The rock of the last-mentioned cone is a fine-grained, flinty, dark rock, which in the field was supposed to represent a peculiar facies of the dark diabase which forms extensive areas about Cathay Hill. An analysis of this

[1] Neues Jahrbuch für Mineral., Beilage Band IV, p. 294.

rock (No. 416), given below, indicates, however, that it is more nearly allied to the peridotites than to the diabases in chemical composition. But a microsection of the rock shows nothing that could be identified as serpentine or olivine. The material is in such fine granules that its nature has not yet been determined. No. 446, of which an analysis is also given, is a fair representative of the diabase of the section, and is a typical diabase in structure and composition. This is from a dike northeast of Hornitos.

Analyses of diabases.

[Analyst, Hillebrand.]

	No. 416 S. N.	No. 446 S. N.
	Per cent.	*Per cent.*
SiO_2	47.75	51.32
TiO_2	.37	1.23
Al_2O_3	10.56	15.28
Fe_2O_3	.74	.47
FeO	8.34	8.59
MnO	.10	.16
CaO	9.62	11.58
SrO	Trace.	Faint trace.
BaO	None.	None.
MgO	19.09	7.25
K_2O	.12	.22
N_2O	1.32	2.92
Li_2O	Trace.	Faint trace.
H_2O below 110° C	.05	.06
H_2O above 110° C	2.06	.95
P_2O_5	.03	.25
Cr_2O_3	.24	....
NiO	.07	....
Total	100.46	100.28

ECONOMIC GEOLOGY.

GOLD GRAVELS.

As in other sections, the Pleistocene gravels along the streams have been and are being mined for gold. Scarcely a trace, however, remains, as far as known to the writer, of the former Tertiary river system of the district, unless there are river gravels underlying the Millerton Table Mountain. Judging from Blake's description,[1] the sediments underlying the lava that caps this mountain are of Tertiary age and were deposited by the waters that filled the San Joaquin Valley at that time, and not by a river.

[1] Pacific Railroad reports, Vol. V.

GOLD-QUARTZ MINES.

The so-called Mother lode terminates near the town of Mariposa, and a study of the mines in that vicinity will bring out much of interest. In the company of Mr. Ludwig, who is associated with the management of the Mariposa estate, the writer visited some of the mines of the neighborhood.

The Princeton mine, which produced much gold many years ago, is part of a long vein having a strike about N. 50° W. and dipping northeast. The north portion of the Princeton lode is in the Sonora area.

Five hundred feet west of the Princeton lode is the Ludwig vein, having the same strike and dipping 60° to the northeast. The latter vein is but partly developed and contains rich ore. The vein is in black slate and varies from 3 to 6 feet in thickness.

South of Princeton, or Mount Bullion post-office, as it is now known, is the McElligot claim, striking about N. 60° W. and dipping 60° to the north. This vein is in hard clay-slate and from 3 to 4 feet in thickness. All of the quartz veins noted here are in the Mariposa formation. Much information concerning the mines of the vicinity may be found in the report by H. W. Fairbanks.[1]

One curious deposit of small extent was seen in serpentine along a streak of talc-schist, near the west border of the large serpentine belt that extends from near Princeton to Mariposa, forming the high ridge just west of the latter town. The exact locality is 1¾ miles a little south of east from Princeton. The deposit consists, besides the talc, of white dolomite looking precisely like that associated with mariposite at the Josephine mine near Bear Valley, pyrite, and a black mineral, the latter occurring in plates with lustrous surfaces in the dolomite. This black mineral was determined by Dr. W. F. Hillebrand to be titanic iron ore (ilmenite). The gold occurs native in the talc-schist, and the pyrite and ilmenite are also saved for reduction. The writer's notes make no mention of quartz in this vein.

It has been previously noted that lens-shaped masses of quartz are very frequent in the schists near the Chowchilla River and to the south and southeast of Daulton's. In most cases this quartz has not been found to contain enough gold to be of economic interest.

Along or in the tongue of mica-schist that extends southeast from the Mount Bullion ridge, as heretofore noted, gold veins have been exploited with varying success. At Sevastopol is a quartz mine in mica-schists, which strike north and south and dip vertically, and judging from the open cut and shaft of the mine this is also the dip of the quartz vein. There is some talc-schist just west of the mica-schist in which the vein occurs. To the south of the Chowchilla River, in the same belt of quartz mines just noted, are the mining camps of Grub Gulch, Coarse Gold, and Fine Gold. At Narbod or Quartz Mountain,

[1] Tenth Annual Report of the State Mineralogist.

to the west of Fine Gold, is a very large quartz vein with gentle dip, much of which is now lying on the surface, being exposed by the erosion of the surrounding granite. A careful examination was made of this vein by Mr. Leo von Rosenberg, who states that this deposit contains gold evenly distributed through the quartz.

Another large quartz mass, likewise known as Quartz Mountain, lies southeast of Hornitos west of the Indian Gulch road. Good ore has been found in this deposit and in this neighborhood.

In the area of soda-granite, in the drainage of Agua Fria Creek, numerous pocket mines have been worked and found profitable.

COPPER DEPOSITS.

In the belt of mica and chiastolite-schists that crosses the Chowchilla River, copper deposits were formerly mined at the Ne Plus Ultra mine, at Daulton's, at Buchanan, and at Green Mountain. In the country rock of the Ne Plus Ultra mine are numerous large crystals of chiastolite. The specimens of ore obtained are composed chiefly of copper pyrite in a gangue which is largely a colorless hornblende. About 50 feet west of the main lode of the Ne Plus Ultra mine are a number of open cuts on a second lode. In this case what appear to be gangue minerals are talc, colorless hornblende, and chlorite. There are also at this point dikes of a beautifully fresh diorite-porphyry. At the Buchanan mine, which is about three-fourths of a mile south of Buchanan post-office, the ore has been taken out of a number of shafts or inclines. The strike of the ledge is about N. 20° W., and the dip 70° to the east. This is also the dip of the inclosing schists, which contain garnets.

The ores seem to occur chiefly along seams of a micaceous mineral which the microscope shows to be a delessite-like chlorite. The microscope also shows that there is more or less colorless hornblende associated with the chlorite, and that the chlorite scales contain very abundant needles of rutile. The ore is made up of copper and iron sulphurets, pyrrhotite, garnet, quartz, chlorite, and reddish-brown biotite. One specimen contains colorless hornblende. The specimens were collected on the dumps of the mine. The Green Mountain mines were not visited.

THE BIG TREES AREA.

GENERAL REMARKS.

The quarter-degree lying directly east of the Jackson area is called the Big Trees area, because in it are the celebrated Calaveras big tree groves, the post-office at the place being known as Big Trees. The main portion of the district lies in the timber belt of the Sierra, with black oak, sugar pine, yellow pine, and cedar as the most abundant trees. In that portion of the district having an elevation of from 3,500 to 4,500 feet the oak, pine, and cedar trees are on the ridge tops, somewhat scattered, the ground being covered with a prostrate evergreen shrub, locally known as "mountain misery," of a bright-green color, resembling at a distance a lawn, the whole producing a park-like effect. There are no sharp mountain peaks anywhere in the area, but rather high, more or less level-topped ranges, which are largely capped with fragmental andesite. Exceptions to this rule are Devils Nose, Blue Mountain, and Mount Elizabeth, quartzite masses lying just west of the main granite mass and forming the easternmost portion of the so-called siliceous series of unknown age referred to in the description of the Sonora area. This belt of siliceous rocks, having a width of about 10 miles and lying to the east of the Carboniferous limestone belt, may comprise rocks of early Paleozoic age. Some statements about the Tertiary rivers are given under the head of "Gold gravels."

According to Whitney[1] the gravel underlying the flat at Vallecito, in the drainage of Coyote Creek, occupies a basin, the bottom of which is lower than that of the Neocene Tuolumne River under the lava ridge just east. The position of the rim rock is said to indicate a westerly course for this lower channel.

The most abundant volcanic material of the Big Trees area, as in most other districts, is andesite-breccia, which at one time covered most of the area. Rhyolite and basalt are also found. On the ridge north of the North Tuolumne and west of Beaver Creek are several small areas of rhyolite, basalt, and a breccia, apparently in the order of age succession as here named, the rhyolite being the oldest. A peculiar biotite-bearing tuff-like lava and an associated black, glassy, basaltic-looking lava contain such a large amount of alkali that they are considered as related to the trachytes, and on account of their unusual character are described in a separate paragraph.

In the northeastern part of the area evidences of the former existence of glaciers are to be noted on every hand. Much of the granite between Highland Creek and Bloods has been beautifully cleared off and smoothed by ice action.

In the canyon of the North Mokelumne, nearly north of Big Meadow Creek, are Hams Salt Springs, at a point where the river at an earlier and higher stage, perhaps in Glacial times, excavated an extensive series of potholes, about 250 in number.[2] The salt water flows into some of these potholes, and on desiccation the salt (NaCl) crystallizes out in beautiful hopper-shaped forms.

TRACHYTE.

In the area of the Big Trees sheet, in 1887, the writer collected some peculiar-looking Tertiary igneous rocks on the north ridge of Beaver Creek, about a mile northwest of the South Grove of Sequoias. The lower part of the igneous mass (No. 86 Tuolumne) is a dark, fine-grained, basaltic-looking rock. The microscope shows the phenocrysts of

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[1] Auriferous Gravels, p. 129.

[2] See Am. Jour. Sci., Vol. XLIV, p. 453.

plagioclase to be near labradorite. There is also augite present. The feldspars of the glassy microlitic groundmass are much more acid than the phenocrysts. Overlying this dark, very fine-grained lava is a somewhat coarser, dark-brown, glassy, fragmental-looking lava containing black mica (No. 85 Tuolumne). The microscope shows this to be a tuff containing biotite and feldspar phenocrysts and microlitic fragments in a brown, glassy groundmass; one large grain of iron oxide was noted. The partial chemical analyses of these rocks indicate that they both may be trachytes. Rocks exactly similar to these were collected by Dr. F. L. Ransome and the writer in the ridge south of Highland Creek, near the east border of the Big Trees sheet and to the west of the Dardanelles.[1] At one point at least they form a layer in the andesite-tuffs, so that it would appear that there were trachytic eruptions during the andesitic period. The possible connection between these trachytes and the basalt of the Tuolumne Table Mountain is noted in the chapter on rock classification. It should be clearly stated, however, that a characteristic trachytic structure has not been noted in any of the thin sections examined, all of which show much glass, and it is likely that the alkalis are to a considerable extent in this undifferentiated base. Future explorations may bring to light more nearly holocrystalline varieties of these lavas. Though they may be regarded as trachytes they are evidently not typical. While biotite is plentiful in the tuff, it has not been noted in the massive form, which throws doubt on the two rocks being closely related. However, near the South Grove, near Clover Meadow, and at other points, the massive lava and the tuff are directly associated. On the ridge north of Soap Creek some trachyte tuff is exposed underlying the andesite-breccia.

Analyses of trachytes (?).

	No. 86 Tuolumne. *a*	No. 85 Tuolumne. *a*	No. 1420 S. N. *b*
	Per cent	*Per cent.*	*Per cent.*
Silica	59.88	61.09	62.33
Lime	5.09	4.94	3.23
Potassa	5.06	5.27	4.46
Soda	3.90	3.69	4.21

a Fireman analyst. *b* Hillebrand, analyst.

The following description of one of the specimens, of which a complete analysis will be found in the table of analyses of the syenite family, is by Dr. F. L. Ransome:

Trachyte tuff (No. 1420 S. N.).

Locality: One and three-fourths miles southwest of Clover Meadow.

Macroscopically, a dark-gray rock of trachytic or andesitic aspect, evidently partially fragmental. Shows small tablets of idiomorphic biotite and small irregular phenocrysts of clear vitreous feldspar.

[1] During the field season of 1896, Dr. Ransome and the writer found these trachyte-like lavas at many points in the Stanislaus drainage.

Microscopically, the greater part of the section is made up of a brown semiopaque glass, in which occurs irregular and better-individualized fragments, showing small lath-shaped plagioclases. Some glassy areas, which appear to be included fragments, show no crystals, and are characterized by a suggestion of minute spherulitic structures. These areas are traversed by a network of fine cracks, either empty or filled with some colorless isotropic substance. The phenocrysts of biotite and feldspar occur in the glassy matrix of the slide. The former is in idiomorphic tablets and has the ordinary character. The most abundant feldspar is a glassy plagioclase in clear, fresh anhedrons, showing sharp albite twinning. The maximum symmetrical extinction angle is about 22°, indicating labradorite. Some untwinned fragments showing a sharp cleavage were suggestive of sanidine. Some grains of feldspar were picked from the hand specimen and tested by Boricky's method. Generally these grains showed only the fluosilicates of sodium and calcium. But one grain showed apparently the fluosilicate of potassium, and the test was confirmed by addition of $PtCl_4$. A minor proportion of the feldspar thus appears to be sanidine. The absence of crystal boundaries and of any quartz for comparison of double refraction makes the determination of the feldspars somewhat unsatisfactory. One irregular fragment of colorless augite was noted in the slide. The rock in its molten condition must have been crowded with fragments of glass and glassy lava, together with the phenocrysts described. It does not appear to be an ordinary clastic tuff, as some of the phenocrysts show some corrosion, and even slight embayments.

GRANITOID ROCKS.

Outside of the potash-feldspar granites noted under the head of "Archean gneisses," and which, with more or less gneiss, forms a wide zone just east of the large area of Paleozoic sediments, the great bulk of the granitoid rocks belong to the quartz-mica-diorite or granodiorite type.

Forming a considerable mass in the drainage of Twomile Creek, in the southeast part of the district, is a very basic rock showing the poikilitic structure admirably. A photograph of a thin section of a specimen of this (985 S. N.) is represented in Pl. XLVII, Fig. A. The dark mineral is brown hornblende, and the inclosed crystals are, at least in part, anorthite. The contact of this poikilitic gabbro with the surrounding granite mass was examined in the bed of Twomile Creek with uncertain results. A specimen taken a few feet from the contact proves to be a granodiorite showing oligoclase, and the specimens of the gabbro from near the contact contain, there as elsewhere, very basic feldspars. Near the contact, however, the gabbro assumes various forms, the hornblendes having a tendency to develop in elongated prisms and the poikilitic structure to some extent disappears. It would appear, therefore, that there is no gradation between the basic gabbro and the surrounding acid granodiorite. In the season of 1896 numerous areas of similar hornblende-gabbros were found.

Throughout the region dikes of granulite and pegmatite are frequent in the granitic rocks. Three and one-half miles northeast of Mount Lewis, in the bed of the North Tuolumne, are numerous pegmatite and granulite dikes, which in part intersect one another. In one instance one dike had been faulted before the intrusion of another, which appeared to follow the fault plane. These dikes are chiefly small, but several of them had a width of from 6 to 8 inches. Some of the dikes contained a broad band of quartz in the middle. Two specimens of two small dikes about 2½ inches in width were collected, one of which (No. 998) contains a middle band of quartz with granulite borders and is shown in Pl. XXXIV, Fig. A, and the other contains a middle band of granulite with massive feldspar borders and is represented in Pl. XXXIV, Fig. B. Both of the specimens in each case figured show the entire width of the dike. The microstructure of No. 998 is shown in Pl. XXXVII, Fig. B. The interlocking quartz grains resemble those of some quartzites. A microphotograph of a thin section of the granulite border is represented in Pl. XXXIX, Fig. A. This granulite is made up of quartz, alkali feldspar, micropegmatite, and plagioclase, with minor amounts of biotite, muscovite, reddish garnet, and minute rutile-like prisms, sometimes in polysomatic growths embedded in the fresh quartz and feldspars. In No. 999 the white feldspar border appears to be a turbid microperthite. Plates of biotite, as may be seen in the figure, cut both the feldspar border and the interior granulite.

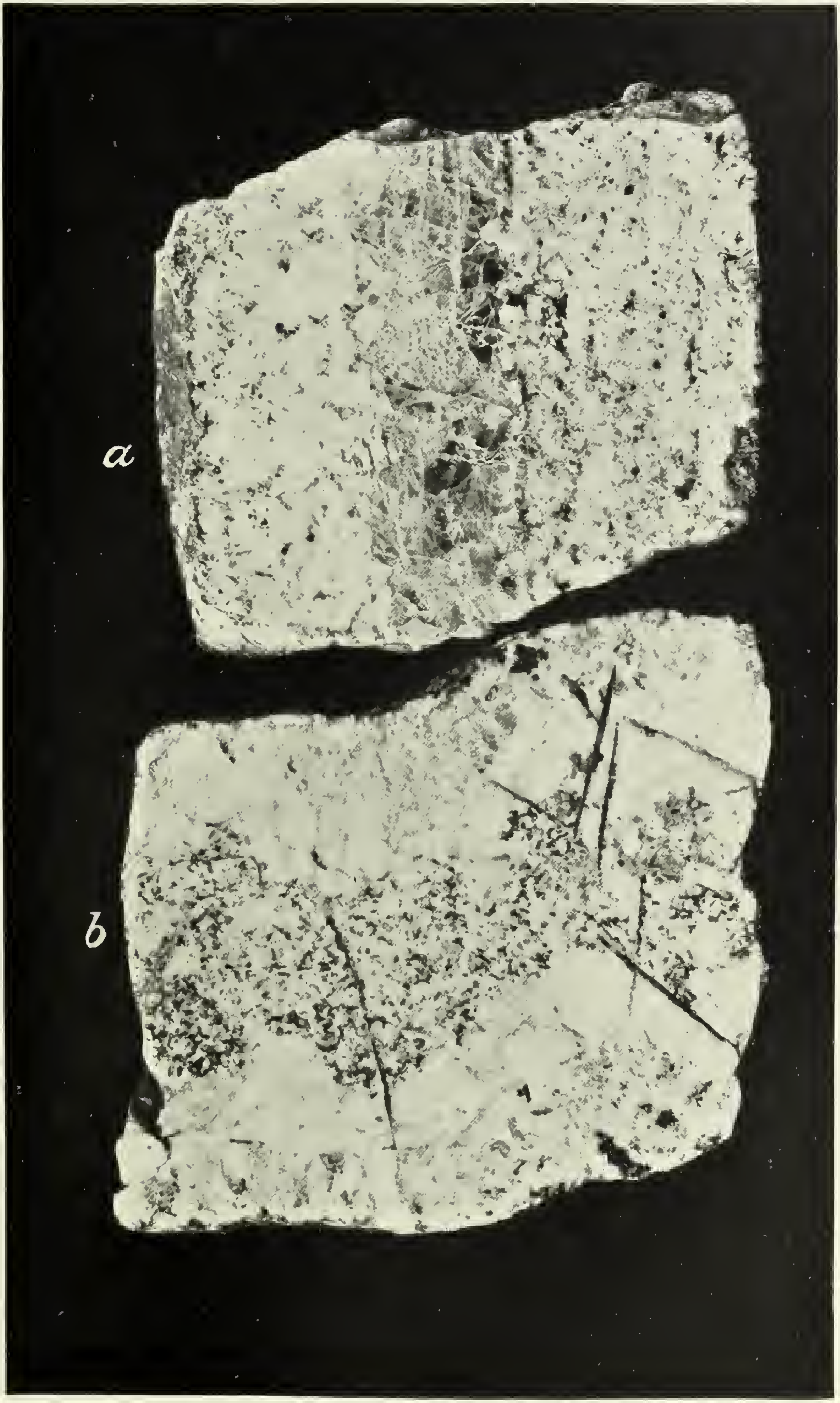
In the northwest corner of the Big Trees area, surrounded by rocks of the Calaveras formation, is a considerable mass of a white coarse-grained rock (No. 1685 S. N.) with numerous dark hornblendes averaging two-tenths of an inch in diameter. The microscope shows this to be a hornblende-syenite. It is composed of alkali feldspar, some plagioclase, and dark-green hornblende, with which is associated apatite. There is also an area of an olivine-gabbro which extends into the Jackson sheet area.

ARCHEAN (?) GNEISSES.

In the canyon of the North Fork of the Mokelumne River is exposed a series of gneisses which may be of Archean age. They are referred to in Chapter I, under the head of Archean gneisses. To the northeast of Devils Nose these gneisses are in contact with the certainly sedimentary series of the Gold Belt of the Sierra Nevada. The rock of Devils Nose is a massive quartzite, and the relation of the gneisses and the quartzite has been only superficially examined. No unconformity has been proved to exist, but the writer expects during the field season of 1896 to examine the contact more closely.[1] The quartzite mass referred to is probably of the same horizon as that of Blue Mountain, to the southeast. The age of the quartzite is uncertain, but there are nearly 10 miles of highly tilted sediments between the quartzite horizon and the pretty certainly Carboniferous limestone of Murphys, Cave City, and Volcano, so that the quartzite may be much older than the Carboniferous.

All of the rocks of the gneiss complex are thoroughly crystalline, and there is thus far no positive proof that any portion of them represents

[1] The field inspection in 1896 brought out no evident proof of an unconformity, but better results are hoped for when the rocks collected are studied microscopically.



a. SPECIMEN FROM GRANULITE DIKE, WITH QUARTZ BAND IN THE MIDDLE
b. SPECIMEN FROM GRANULITE DIKE, WITH FELDSPAR BORDERS.

original sediments. They are no more thoroughly gneissoid at the granite contact than in the middle of the area, and the crystalline condition can not, therefore, be considered as a phenomenon of contact metamorphism, unless it be supposed that this metamorphic action took place during an earlier period, perhaps when the rocks, now typical gneisses, were deeply buried. In any case, the recrystallization must have been brought about by more intense forces than those which have caused the contact zones about the Juratrias granitic intrusions, of which a good example is noted in the description of the Merced-Mariposa district.

In a general way the strike of the gneisses is to the east of north, corresponding in this particular with the so-called Archean masses of western Nevada. To the east is a large area of massive hornblendic granite or quartz-mica-diorite, presumed to be of Juratrias age. The contact of the granite with the gneiss series is beautifully exposed in the rocky bed of Bear Creek, a north tributary, at a point about six-tenths of a mile north of its mouth. The contact is sharp. There are protrusions of the hornblendic granite (No. 1495) into the gneiss, forming distinct dikes, and fragments of the gneiss are also included in the granite. There are also dikes of a white granite (No. 1490) cutting both the gneiss and the hornblendic granite. These latter dikes are but from 1 to 3 inches in diameter, occupying nearly straight fissures, and may be presumed to have been intruded at a later date than the hornblendic granite.

On account of the pressure of other work, it has not thus far been practicable to make a thorough study of these gneisses. They are chiefly thoroughly granular rocks, a fact well brought out in the photomicrograph of No. 1456 S. N., Pl. XXXVII, A.

Titanite, apatite, pyrrhotite, and magnetite are among the accessory minerals. Some of the titanites exhibit a pleochroism in reddish colors, found by Lacroix[1] to be characteristic of that mineral in certain pyroxene-gneisses. Certain light-colored layers containing garnet, quartz, and wollastonite were thought in the field to represent original limestone masses. One stratum, thought in the field to be a quartzite, contains much pyroxene between the interlocking quartz grains and also numerous zircons. By far the greater part of the area is made up of the plagioclase-hornblende-biotite-gneiss. The area has a maximum diameter of about 9 miles, and the rocks are truly gneissoidal in structure, both macroscopically and microscopically, at all points throughout the area.

Associated with the gneisses, and apparently intrusive in them, is a granite, which differs from the Jurassic (?) granite of the region immediately east in containing much potash feldspar and no hornblende, or very little. This granite (Nos. 1452 and 1485 in table of analyses following) is in fact a true granite, while the so-called hornblendic

[1] Bull. Soc. Min. de France, Vol. XII, April, 1889.

granite of Jurassic age is largely a quartz-mica-diorite. The contact of the gneissic series with the hornblendic granite to the east is sharp. Apophyses of this granite extend into the gneisses as dikes, and there are clear-cut inclusions of the gneiss in the granite.

The following analyses, by Dr. Hillebrand, show the composition of some of the gneisses and the igneous rocks that are directly associated with them.

Analyses of gneisses and associated rocks.

	Gneisses.			No. 1458, wollastonite.	Granite.		Quartz-diorite.		Diorite, No. 1481.
	No. 1425.	No. 1473.	No. 1474.		No. 1452.	No. 1485.	No. 1490.	No. 1495.	
SiO_2	57.41	46.63	52.21	50.67	70.43	70.75	69.66	55.86	55.18
TiO_2	1.04	1.82	1.16	.20	.24	.42	.21	1.20	.83
Al_2O_3	17.71	19.49	18.79	6.37	15.51	15.13	17.57	19.30	17.35
FeS_2	None.	.19	.06	None.	Trace.	.06	Trace?	.39	.28
Fe_2O_3	2.16	3.26	2.71	.31	.96	.98	.21	.91	2.77
FeO	5.01	6.63	5.30	.50	1.28	1.43	1.04	4.78	3.90
MnO	.15	.21	.06	Trace.	Trace.	Trace.	Trace.	.16	.15
NiO	.02	.02	Trace.	None.	(?)	None.	None.	Trace.	.03
CaO	6.73	9.15	a8.01 (CaO and SrO together)	40.34	2.76	3.09	4.54	7.31	7.98
SrO	.04	.06		None.	.05	.04	.05	.04	.06
BaO	.09	.14	.08	None.	.20	.12	.03	.13	.04
MgO	3.38	5.37	5.11	.58	.37	.73	.58	2.94	4.80
K_2O	1.82	1.55	1.60	.22	5.14	3.62	.71	1.52	1.42
Na_2O	3.12	3.19	3.31	.14	2.75	3.05	4.91	3.52	3.42
Li_2O	Trace.	Trace.	Trace.	None.	Trace.	Trace.	None.	Trace.	Trace.
H_2O, below 110° C	.20	.10	.12	.08	.08	.10	.05	.19	.16
H_2O, above 110° C	1.14	1.61	1.35	.31	.40	.51	.50	1.23	1.52
P_2O_5	.24	.66	.36	None.	.11	.10	.03	.38	.20
CO_2	None.	None.	None.	.52	None.	None.	None.	None.	None.
Total.	100.26	100.08	100.23	100.24	100.28	100.13	100.09	99.86	100.09
Sulphur	None.	.10	.03	None.	Trace.	.03	Trace?	.21	.15

a Strontia determination failed.

Dr. Hillebrand states: "Although zircoma was looked for in nearly all of the analyses, it was not found. Fluorine and chlorine were in no case tested for. The values of Fe_2O_3 and FeO are based on the assumption that all the sulphur exists as pyrite (FeS_2), and that this is not attacked by hydrofluoric acid during the estimation of the FeO. The error caused by its partial attack would, however. not be large and would affect both the FeO and the Fe_2O_3 values. If the sulphide is in part pyrrhotite the error becomes larger."

Pyrrhotite is certainly present in some of the gneisses, as for example the pyroxene-plagioclase-gneiss (No. 1456) represented in Pl. XXXVII, A, but it has not been identified in the gneisses analyzed, some of which contain iron disulphide in small amount and much magnetite.

Quartz-diorite-gneiss (No. 1425 S. N.).

Locality: Three-tenths of a mile northeast of Clover Meadow, which is to the south of Highland Creek. The area is about 150 feet wide and longer than that in the direction of strike. It is surrounded by hornblendic granite, which invades it in dikes. It also contains dikes of pegmatite.

Macroscopically, a rather coarse-grained, dark, gneissoid rock with rounded or irregular porphyritic feldspars usually less than one-fourth inch in diameter.

Microscopically, it is a thoroughly granular rock, made up of plagioclase, green hornblende, quartz, and brown mica, with accessory biotite, and metallic iron oxide. All the constituents are fresh.

Plagioclase-gneiss (No. 1473 S. N.).

Locality: South bank of the Mokelumne River, about 2,000 feet downstream from the mouth of Bear Creek. There are large amounts of rock like this.

Macroscopically, an even and fine-grained, dark, gneissic rock.

Microscopically, a thoroughly granular rock, composed of plagioclase, much of it twinned on the albite law, green hornblende, brown mica, and grains of iron oxide. Apatite and minute crystals resembling zircon in form and in brilliancy of interference colors are common. It will be noted, however, that no zirconia was found in the chemical investigation by Dr. Hillebrand. Some epidote, showing the usual citron-yellow pleochroism, is present.

Plagioclase-gneiss (No. 1474 S. N.).

Locality: About 150 feet west of No. 1473, on the south bank of the North Fork of the Mokelumne.

Macroscopically, a dark gneiss, with abundant rounded turbid feldspars, larger than the other constituents.

Microscopically, a thoroughly granular crystalline rock, made up of clear plagioclase, nearly always twinned on the albite law; some both on the albite and Carlsbad laws; green hornblende, brown biotite, abundant apatite. The turbid feldspars noted macroscopically show in some cases albite twinning and are therefore not orthoclase. Frequent grains of iron oxide.

Wollastonite-gneiss (No. 1458 S. N.).

Locality: South bank of the North Mokelumne; upstream from the mouth of Bear Creek. Layer in the gneiss series about 20 feet thick.

The piece analyzed, so far as could be determined by an examination with a hand lens, was composed entirely of a white fibrous mineral presumed to be wollastonite in the field. The analysis therefore may be of this mineral only, although it varies considerably from the analyses of wollastonite given in Dana's Manual of Mineralogy, 1892. The stratum contains garnet, quartz, and a biaxial mineral with low gray interference colors in addition to the quartz. Titanite, showing a pleochroism in reddish colors, is also present.

Biotite-granite (No. 1452 S. N.).

Locality: South bank of North Fork of Mokelumne River, about 1¾ miles southwest of Garnet Hill.

Macroscopically, fresh, light-colored granite, biotite, no (?) hornblende; the mica grouped in patches which are roughly in layers, so that the rock has a gneissoid appearance. Some turbid feldspars, larger than the others, from four to five tenths inch in length.

Microscopically, plagioclase, microcline, quartz, and biotite abundant; some grains of metallic iron oxide; less titanite and apatite; microscopic brownish needles in the quartzes, perhaps rutile.

Quartz-mica-diorite (No. 1490 S. N.).

Locality: Bed of Bear River. Dike in the gneiss. An exactly similar dike cuts both the gneiss and the quartz-diorite (No. 1495). This quartz-diorite represents a late intrusion, and is comparable in age and mode of occurrence to the granulite or aplite dikes that cut so many of the granitic masses of the Sierra Nevada.

Macroscopically, white, medium-grained granite, with biotite and some hornblende (?).

Microscopically, structure granulitic, in part granitic or hypidiomorphic—that is to say, the quartz and feldspar grains of nearly even size and generally rounded forms appear to have formed at about the same time. This is true, however, for only a portion of the section, as at other points the quartz is interstitial between nearly idiomorphic feldspars. Many of the feldspars are twinned on the albite law, and at least some also on the Carlsbad law. Some of these are certainly andesine. Untwinned feldspars showing zonal structure are abundant. They can not be orthoclase, as there is too little potassa present. Biotite is rather abundant, but there is little or no hornblende present, in this respect differing greatly from the massive quartz-diorite No. 1495. Titanite and some minute undetermined minerals are likewise present; also chlorite as an alteration product of the biotite, and some epidote.

Quartz-hornblende-mica-diorite (No. 1495 S. N.).

Locality: Bed of Bear River, taken near the contact with gneiss series. This rock is intrusive in the gneisses and is more basic than the average quartz-diorite to the east, of which it is a facies.

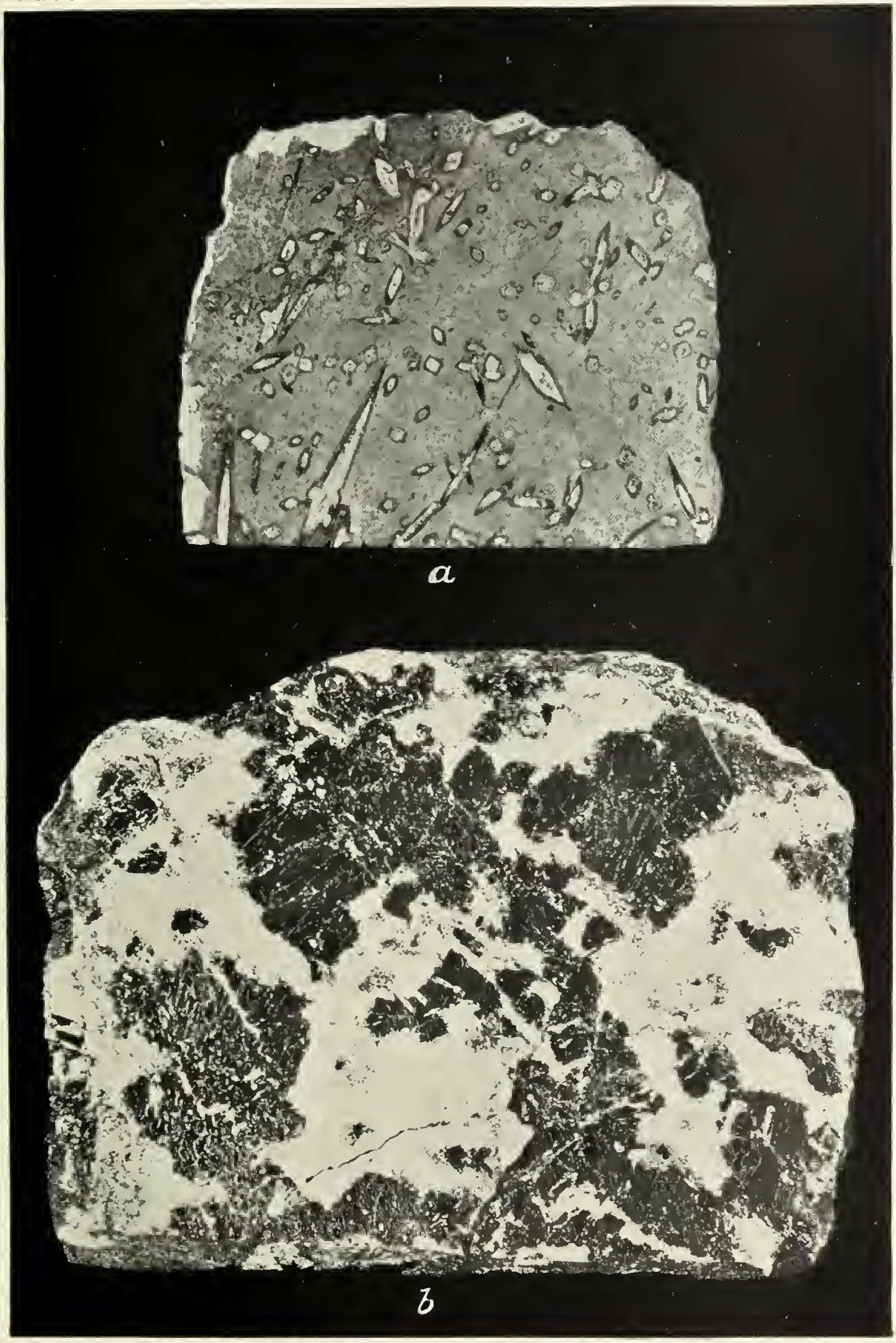
Macroscopically, a white, medium-grained hornblende-biotite granitoid rock.

Microscopically, the rock is hypidiomorphic or granitic in structure. The chief components are plagioclase, quartz, green hornblende, and biotite. In addition to the very abundant albite-twinned plagioclase there are turbid feldspars that show in some cases indistinct albite lamellæ. Apatite, iron oxide, and a zircon-like crystal were noted. Iron disulphide in irregular grains and in one case with crystal form (a parallelopipedon), epidote, and chlorite are also present.

It will be noted that No. 1425 is not from the Mokelumne River area, but from a point many miles to the southeast. This smaller area is without doubt of the same origin as that of the Mokelumne River. At many other points there are dark inclusions in the hornblendic granite, which are believed by the writer to be included fragments of gneisses. Such are the basic inclusions in the granite west of Granite Lake in Tuolumne County, a photoengraving representing which may be found in the previous report.[1] The writer has sometimes referred to these inclusions as "schliere," but this is an error. They do not grade over into the granite, but are certainly inclusions, whatever their origin.

About one-half mile upstream from the mouth of Bear Creek, in the

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, p. 482.



a. JURASSIC CHIASTOLITE-SCHIST.
b. DIORITE-GNEISS.

gneiss series in the bed of the Mokelumne, is a layer of a light-buff rock of medium grain, apparently largely made up of quartz grains with rusty spots and specks of pyrite. In the field this was supposed to be a quartzite, and to give evidence of the original sedimentary nature of a portion of the gneiss series. The microscope shows this rock to be made up of interlocking grains of quartz, monoclinic pyroxene, and garnet, with scattered grains of iron pyrite. There is nothing in the structure of the rock to preclude a sedimentary origin, but the difficulty in recognizing the original nature of a quartz rock may be inferred from an examination of Pl. XXXVII, Fig. B (No. 54), and Pl. XXXVIII, Fig. A (No. 183) and Fig. B (No. 998). In No. 54 the clastic structure is very evident in a portion of the section, and in another part there has been secondary silica added to some of the grains, so that they have been enlarged and interlock to some extent. No. 183 is a massive quartzite in which all of the grains interlock, and from the microscope alone the original clastic structure of this rock can not be affirmed. In No. 998 the quartz grains show the same interlocking structure as No. 183. This rock, however, is a quartz band in granulite, and is certainly not clastic. Moreover, the numerous inclusions and gas and liquid filled cavities of quartzes do not seem certainly to indicate the way in which they were formed, as they occur in rocks having a very diverse origin.

On Pl. XXXV, Fig. A, is represented a peculiar coarse spotted gneiss which was found interbedded with mica-schist in the bed of the North Mokelumne. Intrusive in the gneiss at this point is a granite dike (No. 1479), which is composed of quartz, microcline, some hornblende, and plagioclase; and cutting both the gneiss and the granite dike are dikes of a fine-grained diorite-porphyry (No. 1481), an analysis of which is given above. The coarse spotted rock is believed to have been originally a gabbro-like diorite.

Diorite-gneiss (No. 1479 S. N.).

Locality: Three miles west of the mouth of Bear Creek, in the bed of the North Mokelumne.

Macroscopically, a coarse spotted rock made up of dark patches of hornblende with the intervening spaces filled with a nearly white mineral, apparently feldspar.

Microscopically, the dark patches are made up of large and some small anhedrons of brown hornblende with some biotite, and the white portions of a mosaic of plagioclase grains, most of which show albite twinning. Symmetrical extinction angles measured on 010 of ten of these feldspars varied from 8° to 23°, the average being 15°. The feldspar is probably chiefly andesine. This feldspar mosaic is thought to have resulted from the recrystallization of large crushed saussuritic feldspars, traces of which still remain in certain large turbid grains—that is to say, this biotite-gneiss may formerly have been a coarsely crystalline gabbro-like diorite which had been much crushed, the feldspars being broken up into a mosaic, the recrystallized grains of which now form the white portion of the rock. Apatite is very abundant in the hornblende in large prisms.

GARNET-EPIDOTE LODE.

On the summit of the granite hill that lies just east of the mouth of Moore Creek is an interesting lode, the course of which is north and south. It is made up of white quartz, in which are embedded large prisms of green epidote and a green quartz containing garnets, and is flanked on either side by a band of plagioclase-biotite-gneiss with a nearly vertical dip. The green quartz is seen under the microscope to owe its color to numberless minute crystals of a green monoclinic pyroxene, with some bluish-green fibrous amphibole.

A rough analysis made of the green quartz (No. 1686 S. N.), from pieces picked out so as not to include any garnet, by Messrs. Hillebrand and Steiger, is as follows:

Analysis of No. 1686 S. N.

	Per cent.
Silica	89.6
Iron oxide	3.5
Lime	4.9
Magnesia	2.0
Total	100.0

From this analysis Dr. Hillebrand calculated that about 78 per cent of the rock is quartz, the remainder being chiefly pyroxene.

The garnets likewise contain the same minute pyroxenes noted in the green quartz. One of the remarkable features of the garnets is their large size and finely polished exterior. One imperfect rectangular crystal is about 3 inches long and 2 inches each way in the square cross section.

The lode is not to be seen by the Mokelumne River to the north, nor was it observed on Moore Creek to the south. The tongue of gneiss, however, in which the lode occurs appears to connect with the gneiss on Moore Creek, which is part of the large area before described.

ECONOMIC GEOLOGY.

GOLD GRAVELS.

The gravels deposited by the Tertiary rivers in the area of the Big Trees sheet are largely covered by the lava flows, or have been eroded. Traces of the old rivers, however, are to be seen at a considerable number of points in the western and southern parts of the district. Near Vallecito and Douglas Flat they have been mined extensively by the hydraulic method and by drifting. The Neocene Tuolumne River, a portion of the old channel of which is preserved under the Tuolumne Table Mountain, covered part of the large limestone area west of Columbia, from which the overlying lava had been removed by erosion. Such of the gravels as remained were therefore well exposed for mining, and one of the most interesting sights in the mining region is a view of this old river bottom in which the limestone had been eroded in a very irregular manner, with numerous pothole-like cavities.[1] Many of these were found to be very rich in gold, and the material in them has been largely removed.

GOLD-QUARTZ VEINS.

Probably the most important mine in the Big Trees area is that at Sheep Ranch, which has been worked for many years. The rocks of the Auriferous slate series in the southwestern and western portion of the Big Trees area contain a great number of quartz veins, many of which are as yet undeveloped. A very promising region is that east and northeast of Columbia and American Camp, in the southern portion of the area. The Keltz mine, the Star mine, and some others are now in operation. Some time since the writer visited a number of the mines in this section, and some brief notes to indicate the kind of sulphides that accompany the ore are herewith appended. Some of these mines and others have undoubtedly been developed since the time of the writer's visit, and the notes therefore in no way represent the present condition of the mining industry in this section.

The vein of the Eagle quartz mine on Eagle Creek, from 6 inches to 3 feet in thickness, strikes nearly north and south magnetic, dipping to the east about 44°. The country rock of the mine is the Calaveras formation. A dike was noted along the vein. Several specimens of the ore were obtained, one of which shows free gold. Zincblende, iron, and copper pyrite form part of the ore.

The Star quartz mine is in schist on the north side of Rose Creek. Nearly all of the quartz seen is of dark color. It is said to be very rich in spots. The specimen of ore obtained is black quartz showing iron pyrite. The Star mine has recently been reopened and a rich body of ore found, containing free gold and sulphides of iron, copper, and lead.

The Riverside mine is on the north side of the South Fork of the North Stanislaus. Where seen the vein is a strong one, upward of 5 feet in thickness, and is composed largely of ribbon quartz. The ore shows both copper and iron sulphides. On the south side of Knights Creek, in a granite area, was noted a prospect, the ore of which contains iron pyrites and black scales with metallic luster resembling graphite. These proved on blowpipe analysis to be molybdenite. The quartz of the ore is dark in color. The claim is known as the Dorsey quartz mine.[2]

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[1] Many of these cavities, however, may not have been formed in the ordinary manner, by the revolving of pebbles on the rock bottom of a stream. Some of them appear to have dissolved out of the limestone and to be a phenomenon of secular rock disintegration. Thus, in the limestone at Murphys, south of the west end of the town, may be seen an exposure on the hillside where similar cavities are filled with red soil.

[2] This should not be confused with the Dorsey mine on the ridge north of Knights Creek. The ridge mine is in slate.

North of Murphys, in the limestone, the Willard Mining Company has exploited the Blue Wing vein. This deposit is of much interest on account of the unusual association of the sulphides in the ore. The ordinary vein quartz forms a part of the deposit, but it is accompanied by brown jasper. Cinnabar, or sulphide of mercury, stibnite, and galena are present in the ore. Bird's-eye porphyry, apparently an altered diorite, cuts the limestone into dikes. The vein is said also to contain copper.

To the west of Blue Mountain is a group of mines, the ores of which are very basic. Greve's claim, between Licking Creek and the South Fork of the Mokelumne, has an ore containing iron pyrite and a galena-like sulphide. The Cook mine, north of Licking Creek and about a mile northwest of Greve's ranch, contains a large amount of very basic ore composed of iron pyrite, zincblende, and an arsenic sulphide. Much of the ore is said to be worth $100 per ton. The mines at the abandoned camp of Blue Mountain City are in quartzite, and the ore contains sulphides of lead, antimony, silver, and probably arsenic. The Heckendorn mine is now (1896) being reopened.

The Belle View mine, formerly known as the Hyde, is in the same granitic area as the mines of the Soulsbyville district in the Sonora area. Unlike most of the mines of that district, there are not large amounts of sulphides in the Belle View ore. Galena, containing some antimony, and copper and iron pyrite were noted in small amounts.

THE DARDANELLES AREA.

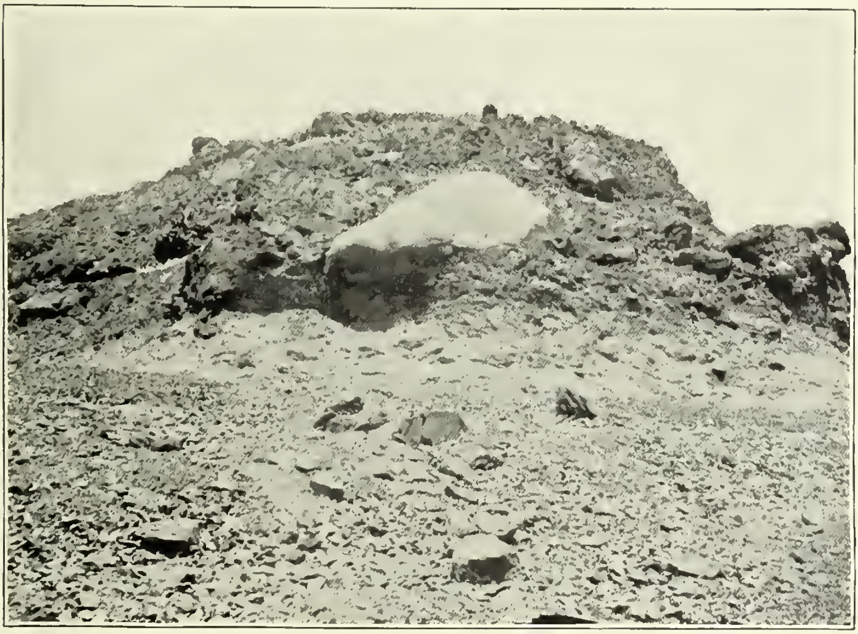
Lying immediately to the east of the Big Trees area is a region of high, rugged mountains, many of them largely built up of volcanic materials. Tower Peak, in the southeast part of the area, reaches an altitude of more than 11,500 feet.

The sheet is named from the very picturesque bluffs, composed of lavas, which bear the name of The Dardanelles, the highest point being known as the Dardanelle Cone.

The lavas of these bluffs are, to a considerable extent, massive, basaltic-looking rocks. At the northwest base, south of Highland Creek, there is also some rhyolite.

The andesite-breccias are here, as elsewhere, abundant. They are in general roughly stratified. A view taken of the andesite ridge north of the road from the Big Trees to Markleeville is reproduced in Pl. XXXVI, A, and shows the imperfect stratification. In the neighborhood of the Highland Lakes there are numerous bowlders of granite in the andesite, one of which is shown in Pl. XXXVI, B. This is from a photograph taken a little southwest of the Highland Lakes. In the same vicinity there are dikes of light-gray hornblende-andesite cutting other dark-colored andesitic masses. On the summit of Arnot Peak, which has an elevation of 10,000 feet, the lavas are chiefly or entirely andesite, some of which, in the form of tuff, is distinctly stratified. The

A



B

A. RIDGE OF ANDESITE-BRECCIA NORTH OF THE BIG TREES ROAD IN ALPINE COUNTY.
B. GRANITE BOWLDER EMBEDDED IN ANDESITE-BRECCIA.

breccia mountains along the crest of the range just south of Sonora Pass likewise are arranged in layers.

Glacial markings were noted everywhere above an elevation of 7,000 and below 10,000 feet, giving evidence that a nearly continuous ice sheet covered all the upper part of the range, only rugged peaks and ridges projecting above it. There must have been movement in this ice sheet, even on the very summit of the range. Thus, in the sag of the divide, 2½ miles northwest of Tower Rock, through which a trail to Bridgeport passes, glacial polish and striæ may be seen, indicating movement both east and west—that is to say, the striæ extend across the dividing line of the drainage easterly to the Great Basin and westerly to the Pacific. There is a sharp and rugged peak just to the south of the pass referred to, but no eminence of any size directly to the north. It is impossible that an ice mass should have here moved up over the pass from one side and down on the other, which would satisfactorily account for the continuous striæ at the very summit of the divide, for there is no névé basin on either side of the divide at this point where ice and snow could have accumulated in sufficient amount to force a tongue of ice over the divide. It may be supposed that there was a considerable thickness of ice all over the pass, and that movement on the lower surface of this mass began at the dividing line of the east and west drainages, one portion of the ice traveling east and the other west.

What appears to be a residual glacier may be seen on the north slope of a very steep and high ridge 2 miles northwest of Tower Peak. At any rate, at the base of the snow bank, the under portion of which is ice, the mass of débris had the appearance of being pushed ahead. The elevation of the ridge was more than 10,000 feet. By the Sonora and Mono road, the main mass of the granite in the Dardanelles area is a coarse type, with porphyritic orthoclase or microcline crystals, some of which attain a length of 3 inches. This is quite the same rock as that described in the previous report under the head of granite-porphyry.[1]

Much of the granite of the neighborhood of Tower Peak shows evidence of compression, in places resembling a stratified rock. There are in this vicinity numerous small areas of thoroughly crystalline schists included in the granite, and many of these schist masses form the serrated summits of peaks, giving to the region a very wild and rugged appearance, much enhanced by the ever-present snow banks and the lack of vegetation, except prostrate shrubs and trees (willow and pine) with their branches so close to the ground that one can walk on them.

At one point, 3 miles north of west from Tower Peak, is a considerable mass of quartzite, marble, and black fine-grained gneiss. At the edge of the coarsely crystalline white marble, which has a width of about 400 feet, is a white schistose rock, which the microscope shows

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, pp. 478-480.

to contain pyroxene. Granitoid dikes and quartz veins cut both the limestone and the schist. The granitoid rock proves on microscopic examination to be a fresh quartz-diorite, containing primary augite and titanite. One of the quartz veins at the contact of the limestone and schist had been prospected. There is much green epidote, garnet, and zincblende, and a bright bluish metallic sulphide (?), in this vein.

The black gneiss, referred to as being part of the same area as the quartzite and limestone, extends south and forms the summit of a point which is 2¼ miles due west of Tower Peak. The contact of the gneiss and granite, which is plainly to be seen on this point, is sharp, and there are angular and rounded fragments of the schist in the granite. This gneiss is composed of brown mica, hornblende, and plagioclase, with a tendency to a lath-shaped development, with porphyritic plagioclase scattered through the rock.

THE YOSEMITE AREA.

The main interest in this region centers in its scenic marvels—the Yosemite Valley, with its beautiful waterfalls and magnificent cliffs, the Hetch-hetchy Valley, and the Grand Canyon of the Tuolumne. In the southwest part of the area, in the Auriferous slate series, are numerous quartz veins rich in gold, and there are large tracts of the western portion covered with magnificent timber. The larger part of the area is included in the Yosemite National Park. This region has been intensely eroded since the period of Tertiary volcanic activity, so that only mere traces of the former volcanic materials are preserved. Areas of fragmental andesite are to be seen on the ridge south of the main Tuolumne, to the west of the Hog ranch, on Rancheria Mountain, and on the flat-topped ridge east of Piute Creek. On Rancheria Mountain there is also some basalt, as well as well-worn gravel, indicating a former stream there.

The southwest fourth of the district is made up chiefly of the Auriferous slate series, and the larger part of the remainder of quartz-mica-diorite or granodiorite. Both Yosemite and Hetch-hetchy valleys are carved out of the latter rock. On the east slope of Mount Hoffman is a small area of quartzite. By far the larger part of the granitic rocks have been polished and scored by glacial action, the polish still being preserved at many points.

In the Grand Canyon of the Tuolumne River, in Pate Valley, Dr. Becker and the writer noted glacial markings close to the water's edge in August, when the water is low, showing how little cutting has been done since the Glacial period. The Grand Canyon has here a depth of 5,000 feet. On the ridge south of the Tuolumne, by the trail from Hog ranch to Hetch-hetchy, the writer observed in the moraines blocks of schists similar to the schists in the Mount Dana area, and it is therefore probable that these blocks traveled on the ice a distance of more than 30 miles. It is expected that a geologic map will be made of the Yosemite area in the near future.

THE MOUNT DANA AREA.

The area of the Mount Dana sheet comprises one of the most picturesque portions of the higher Sierra, and, unlike that portion of the range that lies farther south, it is easily accessible, there being a wagon road into it from the Yosemite district and trails leading up to it from the eastern slope at several points. As yet very little is known of the geology of the region.

The first accurate statement of the geology appears to be that by Professor Whitney,[1] whose parties visited the district in 1863. Professsor Whitney's notes refer chiefly to the scenic aspects of the country and to the glacial geology, but attention is likewise called to the slate belt of which Mount Dana and Mount Lyell are the most prominent points. These mica-slates, or more properly schists, are said by Professor Whitney to form a belt which in Mono Pass is from 3 to 4 miles wide, the general strike being N. 30° W. and the dip at a high angle to the east or northeast. The contact with the granite is everywhere sharp. Mount Dana is said to be made up of metamorphic slate dipping to the northeast at a high angle. Bright reddish-brown sandstone passing into epidote rock is said to form much of the mountain on the south side. This is the sandstone which is referred to later as being perhaps of Juratrias age.

In connection with his study of Mono Lake basin, Prof. I. C. Russell visited the high Sierra region, and some interesting allusions to the picturesque scenery, with excellent photoengravings of mountain views, and much information about the glaciers, present and past, may be found in his monograph.[2] But he made no attempt to study the complex of the older rocks. A portion of Mono Lake basin is included in the Mount Dana area, and Professor Russell's account of this portion of the district contains descriptions of the lake beds, moraines, Pleistocene volcanoes, recent faulting, and much other material of great value. References to papers by Le Conte, Reyer, and McGee on the Mono basin will also be found in Russell's monograph.

In the reports of the State mineralogist of California, Mr. L. P. Goldstone[3] and Mr. W. C. Watts[4] give some facts about the iron and silver mines of the Minarets district, and a few facts about the precious-metal deposits of the Tioga district and of Mono Pass have been published by the writer.[5]

The enterprising members of the Sierra Club of San Francisco are familiar with the district, and in several of the bulletins of the club may be found descriptions and good illustrations of the scenery.

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[1] Geology of California, Vol. 1, pp. 425-437.

[2] Quaternary history of Mono Valley, California: Eighth Ann. Rept. U. S. Geol. Survey, Part I, 1889, pp. 261-394.

[3] Tenth Ann. Rept. State Mineralogist, p. 191.

[4] Eleventh Ann. Rept. State Mineralogist, p. 214.

[5] Am. Jour. Sci., Vol. XLVII, p. 469, and Vol. XLIX, p. 379.

The writer has made two trips into the Mount Dana area, the last one in company with Dr. G. F. Becker. No attempt will be made to give any connected account of the geology, for which, indeed, material is not yet in existence.

The writer's observations confirm those of Professor Whitney as to all the important points. The slate belt referred to by Whitney was examined in Mono Pass, along the ravine on the south side of Mount Dana, in Glacier Canyon on the north side of the mountain, on the ridge west of McLanes Pass, on the east slope of Mount Conness, and by the trail to Lundy. As stated by Whitney, the general dip of these slates is northeasterly at a high angle, sometimes vertical. Some exceptions to this will be noted.

A considerable number of specimens were collected. On the ridge west of McLanes Pass the following succession was noted, starting from the granite contact on the west and going north:

	Feet.
1. Granite, the east border of the great area forming most of the range to the west, including the summit of Mount Conness. See Nos. 39 and 40 in the tables of analyses of the granite family in the chapter on rock classification.	
2. Schistose rock, which is composed, as seen under the microscope, of quartz, feldspar, and biotite, and may be perhaps a schistose form of the granite.	20
3. Fine-grained quartzite or arenaceous slates, with some schists like the preceding	400
4. Chiefly quartzite	1,700
5. Schists derived from old andesites (porphyrites) (Nos. 72 to 74 Mono). The cryptocrystalline granular groundmass appears to have been derived from the devitrification of glass, in which case they may be called apoandesites. The dip of the rocks at this point is 75° southwesterly. About	3,000
6. Quartzite, knotted schists, etc. The rocks along here dip to the southwest 65°	5,000
7. Small body of granitic rock intruded by a porphyry.	
8. Beyond this are the schists in which is the Tioga gold-quartz vein, which continue across the strike for perhaps 2 miles. These also dip to the southwest, as far north as the mining camp of Tioga.	

All the schistose rocks in the above-described section are conformable throughout, striking northwest (from 30° to 40° west of north) and dipping near the granite nearly vertically; but farther north, or away from the granite, the dip is to the southwest at angles of from 65° to 75°; and this is true also of the same series as far north as Tioga, a distance from the main granite mass of 2 miles. The trend of the ridge on which the section was measured is north and south, and therefore not at right angles to the strike of the rocks. It is estimated that the actual thickness of the beds is about one-half the above-given distances. It should, moreover, be stated that the supposed bedding of these rocks may be in part schistosity.

In Glacier Canyon (so named from a diminutive glacier that still exists at its head), on the north side of Mount Dana, the schists are finely exposed. As a rule they strike northwesterly and dip vertically or to the northeast at angles of 75° or more. The specimens brought back from Glacier Canyon show beyond any possible doubt that the schists are in part made of ancient andesitic lavas. One of the specimens is a well-preserved andesitic breccia. Similar schists were also found on the east side of Mount Dana, about 1,000 feet vertically below the summit, interbedded with argillaceous schists and dipping easterly perhaps 60°. There is therefore no doubt that during the formation of the schist series of the Mount Dana–Mount Lyell area volcanoes existed and supplied material from which a portion of the schists were made The age of these schists is not known, but they are supposed to be Triassic or Paleozoic.

In Glacier Canyon a stratum of limestone from 1 to 3 feet wide was noted. To the south of Glacier Canyon, near its mouth, are some thinly laminated black slates, striking about N. 30° W., in which is a limestone stratum about 5 feet thick and a layer of volcanic conglomerate. In the clay-slates and limestone at these points and elsewhere a search was made for fossils, but without success.

On the summit of Mount Dana there is a large amount of a reddish sandstone in which layers of epidote have been developed. These tuffaceous sandstones dip at comparatively gentle angles (30° to 45°) to the southwest. No trace of these red rocks was found at any place about the lower part of the mountain, nor are they represented in the schist series about Tioga, in Mono Pass, or east of Mount Conness. There is good reason to believe that they lie unconformably on the schists. Although sufficiently unaltered to afford determinable fossils, none were found. These sandstones form a mass several hundred feet in thickness. When first seen by the writer, they seemed quite comparable to the red Jurassic sandstones of Mount Jura, in Plumas County.

ECONOMIC GEOLOGY.

The Tioga gold mine, about 3½ miles northwest of Mount Dana, was worked for some time by means of tunnels. The May Lundy mine is situated on the west side of Lake Canyon, which drains into Mill Creek. The buildings at the mouth of the tunnel are most picturesquely located on the very steep hillside, perhaps 800 feet above the little alpine lake in the canyon below. The gold quartz of the vein is said to occur in the granite, but not far from the contact with the slates which cap the ridge above.

In the schists of Mono Pass are numerous quartz veins charged with sulphides. None of the ores seen could be treated by a free-milling process. The specimens (No. 455 S. N.) collected there by the writer from the Golden Crown ledge were examined by Prof. R. L. Packard, who reported that the sulphide is tetrahedrite or an allied mineral giving blowpipe reactions for sulphur, antimony, copper, lead, and iron. The ore is presumed to contain silver, and perhaps gold, but neither of these was determined. Tetrahedrite is a rather rare mineral in the California gold veins.

Some of the claims in the Lee Vining Creek drainage were visited by the writer in 1886. Some specimens from the Isabell claim were submitted to Dr. W. H. Melville, who assayed them with the following results:

No. 876, Sierra Nevada collection:

(*a*) Chiefly made up of zincblende; contains 5 ounces gold and 7 ounces silver to the ton.

(*b*) Largely iron and copper pyrites; contains a trace of gold and nearly 16 ounces silver to the ton.

(*c*) Contains a large amount of arsenical pyrite; 51 ounces gold and 32 ounces silver to the ton.

The above samples probably do not represent an average of the ore, and are given merely to show the association of minerals in the vein.

On the southwest slope of Mount Gibbs some heavy ledges of dark ore have been prospected for silver. A specimen of the ore from one of these ledges (No. 879 S. N.) was submitted to Professor Clarke for assaying. The assay, made under the direction of Professor Munroe, of the Columbian University, gives only a trace of gold and 1½ ounces silver per ton. This ore is therefore of no economic value. Some blowpipe tests, made by Mr. Steiger, show that the ore contains iron, antimony, and sulphur, and Professor Clarke is of the opinion that the mineral berthierite may be present. If so, this will be the first time this mineral has been found in California. An analysis will be made of the ore at a later date.

The mines in the Minarets district appear to be in the same belt of schists as those above referred to. They are described in the Mining Bureau reports as being chiefly iron and silver deposits. A specimen of ore from Reynolds's "Sierra Gold and Silver Mine" from this district was given the writer by Mr. C. L. Mast as containing bismuth. This specimen is a piece of quartz charged with copper sulphide and a galena-like sulphide which was examined by Dr. Hillebrand, who states that it is sulphide of bismuth.

THE KAWEAH RIVER DRAINAGE.

The Kaweah River drains a comparatively small area to the west of the high ridge that lies just west of the head of Kern River. The high points of this ridge, about 40 miles north of east from Visalia, are known as the Kaweah Peaks. On reaching the east border of the San Joaquin Valley the river divides into a network of creeks, and irrigation canals carry off much of the water. The first foothills lying directly east of Visalia are on the south side of Yokall Creek. There is here a central mass of light-gray, rather coarse biotite-granite, surrounded on the west and north by a dark-colored dioritic rock (perhaps a uralite gabbro), apparently largely hornblende. The hills to the east and south appear to be made up of the same hornblende rock, but they were not examined. The contact between the granite and the dark rock is sharp. The granite area is known as Rocky Point. Here, on the protected face of a huge granite cropping, are a number of curious figures drawn in white, red, and black pigments, evidently the work of Indians. A rough drawing of these is reproduced in a report by the late Col. Garrick Mallery on picture writing.[1] On a small knoll to the northeast of Rocky Point there is some mica-schist, talc, and serpentine, with a quartz vein.

About 6 miles northeast of Visalia is a considerable hill, largely made up of iron-stained siliceous argillite and light-colored quartzite, with a nearly east-west strike and dipping 70° to the south. There is said to be iron ore in the hill.

About 8 miles northeast of Visalia is a little butte from which a specimen was collected. This rock (No. 459 S. N.) proves to be a fine, fresh gabbro, containing both rhombic and monoclinic pyroxene. These two hills stand out in the valley region. At the limestone quarries 10 miles from Visalia, near Limekiln post-office, the limestone, or rather marble, is a coarsely crystalline rock, intersected by a set of nearly vertical east-west fissures and a more or less nearly horizontal set. The limestone is also penetrated by diorite dikes, some of which lie very flat, others being vertical. It is likely that the dikes are intruded along the fissures of the systems above noted. Diorite dikes like those in the limestone are to be seen in the granite to the southeast, by the main road.

On the east side of the hill, facing the Kaweah, which here makes a bend, there are layers of siliceous argillite, quartzite, and limestone, interbedded. The layers of quartzite are from one-fourth inch to an inch in thickness, and the intervening limestone layers from 1 to 3 inches in thickness, and have been folded on a minute scale, giving a convoluted appearance to the layers.

Just east of the mouth of the South Kaweah is a sharp cone, known as Marble Mountain. On the summit of the ridge, to the east of the marble mass, is some garnetiferous quartzite, also layers or veins of garnets, and a gneiss with an evenly granular structure, made up of quartz, feldspar, biotite, muscovite, and grains of iron ore.

All of the lower portion of the Kaweah drainage is not, however, made up of rocks like those above noted. There is much granite in which the various sedimentary masses form areas of varying size. In the schist series are numerous granitic dikes, which are not like the prevailing gray granite, and doubtless represent later intrusions (granulite and pegmatite).

Mineral King is an abandoned mining camp near the head waters of a branch of the Kaweah. As was noted in the previous report, there is here a lens of sediments inclosed in the granite which contains casts of fossil shells presumed to be of Triassic age. The granite to

[1] Tenth Ann. Rept. Bureau of Ethnology, p. 53. See also plate opposite p. 387 of Twelfth Ann. Rept. State Mineralogist of California.

the west of this lens is a gray rock, and was presumed in the field to be a granodiorite. But one specimen of it was taken (No. 463), and this proves to be a granite containing much potash feldspar and some quartz, oligoclase, and biotite. The amount of feldspar is so large that it might be called a quartz-syenite. However, another specimen, collected on the south side of the stream, proves to be of the granodiorite type.

At the west border of the lens of Triassic rocks the first specimen collected is a mica-schist, just east of which is a hundred feet or more of a gneissoidal rock (No. 466). The microscope shows this to be made up chiefly of quartz grains and a mineral with low interference colors, high relief, and extinction sensibly parallel to the dominant cleavage. It is probably zoisite. A portion of the zoisite (?) grains show the rose-red pleochroism characteristic of thulite, a manganiferous zoisite. About due east of the old mining camp is the sharp point known as Sawtooth, having an estimated elevation of 13,000 feet. In the canyon which heads at Sawtooth, draining westerly, there is a fairly good trail. Along the trail to the east of the mining camp is some limestone, and still farther east are some beds, in part conglomerate, containing altered andesitic material, indicating the existence of volcanoes in Triassic time in this region. The metasilicates of these old andesites are altered to uralite and epidote, but the feldspar phenocrysts are still fresh. There is a layer of quartzite, perhaps 1,200 feet in thickness, on the east border of the sedimentary lens. To the west of this quartzite there are masses of granite-porphyry and granodiorite intrusive in the schists. The strike of the series as a whole is nearly north and south, with a high dip, sometimes vertical. There is chiastolite-schist in the collection from Mineral King, the locality given being Monarch Canyon.

The granite to the east of the Triassic lens forming Sawtooth Peak is a typical potash-feldspar granite with black mica. From the crest of the dividing ridge, of which Sawtooth is a prominent point, one may see, looking east, a glacial amphitheater about a mile in width, in which are two lakes, one perhaps a mile in length. There are sharp peaks both to the north and to the south of this amphitheater.

The Mineral King sedimentary lens extends south to Farewell Gap and beyond. The width at the camp is perhaps 1½ miles.

CHAPTER VI.

CLASSIFICATION OF THE ROCKS.

There is a present tendency among writers on petrography to base the classification of rocks on those characteristics which can be determined from the rock specimen itself. Thus Michel-Lévy writes:[1]

> One sees from all that precedes that it is necessary to base a rational petrographic classification upon contingent facts, independent ot geogenetic hypotheses, and that the consideration of the age of rocks from this point of view is as hypothetical as that of their conditions of occurrence (*gisement*) in the depths or at the surface. Given a sample of rock from an unknown province, it is indispensable, and it is possible, to name and describe it without amphibology. It is possible to determine from it with certainty neither the occurrence nor its geological age.

Iddings[2] states practically the same thing in his monograph on the rocks of Electric Peak and Sepulchre Mountain, and other prominent authors may be quoted to the same end. There can be no doubt that nothing is more needed to advance petrographic science than the definite use of rock terms; and if it is necessary to know the conditions under which a rock consolidated and its geological age, it is evident that in many cases we can not name a rock at all. No mineralogist would consent for a moment to base a classification of minerals on other than contingent facts; and although, since rocks are in most cases mixtures of several minerals, a rock classification must be a classification of mixtures, which vary in each magma from point to point, it is nevertheless true that certain mixtures of very nearly the same composition and structure are found in many parts of the world, and admit of being characterized in such a way that the term applied to them may be made to have a definite meaning. On the other hand, if the fact that rocks are mixtures be not borne in mind, the tendency to make rock species may be carried to excess. If the minerals that make up the larger part of most igneous rocks were great in number, a rock classification would require so many terms as to have little practical value; but, happily, as all geologists know, this is not the case, and, with the enormous advance in late years of our knowledge of the composition of rocks, it is perhaps not visionary to hope that a set of terms which will endure will soon be agreed upon for the most universal mineral mixtures.

For many of the coarse granular rocks, in which the mineral components are easily recognized, there is already a set of terms in use nearly

[1] Structures et classification des roches éruptives, Paris, 1889, p. 34.

[2] Thirteenth Ann. Rept. U. S. Geol. Survey, p. 663.

the world over, but with many rocks occurring as dikes, and with the microcrystalline and cryptocrystalline rocks, there is still much confusion. What appears to be a step in the right direction is the division by Fouqué and Michel-Lévy of the plagioclase rocks into an oligoclase-andesine series and a labradorite-anorthite series. The former will contain most andesites and diorites, and may be called the diorite family; the latter will contain most basalts, diabases, and gabbros, and may be called the gabbro family.

This method of dividing the volcanic plagioclase rocks, the basalts and the andesites, has long been in use in France, and also in Germany, for, in restricting the basalts to soda-lime feldspar rocks with not more than 56 per cent of silica,[1] and the andesites to those with more than 56 per cent of silica, nearly all the basalts are labradorite-anorthite rocks and nearly all the andesites are oligoclase-andesine rocks. But the separation of diorites, diabases, and gabbros on the basis of the feldspars has never been systematically carried out, so far as known to the writer, except by the French school, and even with them the terms diorite, diabase, and gabbro are used for both intermediate and basic rocks, their character being indicated by the use of an adjective. Thus Michel-Lévy speaks of *diabase andésitique* (oligoclase-andesine diabase), and *diabases* or *gabbros labradoriqes*, or *anorthiques*. If petrographers can be induced to call all oligoclase-andesine granular rocks diorites, and all labradorite-anorthite granular rocks diabases and gabbros, the nomenclature of the granular plagioclase rocks will be greatly simplified.

Although Rosenbusch does not exclude rocks with basic plagioclase from his diorite group, he nevertheless remarks in the last edition (1895) of Massige Gesteine, pp. 213–214, . . . "still, rocks with basic plagioclase are comparatively rare; oligoclase and andesine prevail." On page 279 he further remarks: "In the thoroughly normal gabbros a plagioclase more acid than labradorite can scarcely be found."

Professor Brögger[2] has practically carried the scheme above noted into effect in a recent publication in which a scheme of the quantitative, chemical, and mineral composition of rocks is taken into account more narrowly than usual. In this way of grouping, all rocks of approximately the same mineral and chemical composition are brought together in families without regard to their structure, age, or the mode of their occurrence. Thus the granite family of Brögger will include granite, granite-porphyry, and rhyolite, and the diorite family (medium acid plagioclase rocks) both diorite and andesite. This method of grouping the rocks seems to the writer most desirable, and is essentially followed also by Michel Lévy, Teall, and Zirkel. A rough sketch of such a classification, in so far as it applies to the rocks studied by the writer in the Sierra Nevada, is herewith appended. This is obviously very incomplete, and, moreover, contains practically nothing original.

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[1] Rosenbusch's Massige Gesteine, p. 702.

[2] Die Eruptionsfolge der triadischen Eruptivegesteine bei Piedazzo in Südtyrol, Kristiania, 1895, p. 60.

The feldspars, usually the most abundant element, are the main basis of classification in the feldspathic rocks. The ferromagnesian elements offer a convenient means of distinguishing the rock species. Four grades of crystallization can be discerned in most of the families, the three first being holocrystalline, viz:

1. Macrocrystalline: the elements determinable without a microscope.
2. Microcrystalline: the elements determinable only by the aid of a microscope.
3. Cryptocrystalline: although, like the others, entirely crystalline, the elements are in large part too small to be identified even with the microscope.
4. Glassy.

The above terms refer only to optical analyses; of course any constituent of any rock, coarse or fine, that can be separated from the other elements can be determined by chemical analysis.

GRANITE FAMILY (alkali feldspar and quartz).

Granite: structure hypidiomorphic or granitic.
Biotite-granite.
Hornblende-granite.
Augite-granite.
Granulite Michel-Lévy (*aplite* Rosenbusch): structure granulitic.
Granite-porphyry (*microgranite* Michel-Lévy in part): groundmass microcrystalline.
Quartz-porphyry (rhyolite-porphyry): groundmass cryptocrystalline.
Rhyolite.

QUARTZ-DIORITE FAMILY (oligoclase-andesine-feldspars and quartz).

Quartz-diorite: structure hypidiomorphic or granitic.
Quartz-diorite-porphyry: groundmass microcrystalline.
Dacite-porphyry: groundmass cryptocrystalline.
Dacite: structure microlitic or glassy.

SYENITE FAMILY (alkali-feldspar).

Syenite: structure granular.
Hornblende-syenite.
Mica-syenite.
Augite-syenite.
Syenite-porphyry: groundmass microcrystalline.
Trachyte-porphyry: groundmass cryptocrystalline.
Trachyte: structure microlitic or glassy.

DIORITE FAMILY (oligoclase-andesine-feldspars).

Diorite: structure granular.
Hornblende-diorite.
Mica-diorite.
Augite-diorite.
Diorite-porphyry: groundmass microcrystalline.
Andesite-porphyry: groundmass cryptocrystalline.
Andesite: structure microlitic or glassy.
Hornblende-andesite.
Augite-andesite.
Hypersthene-andesite.

GABBRO FAMILY (labradorite-anorthite-feldspars).

Gabbro: structure granular or poikilitic.
Hornblende-gabbro.
Pyroxene-gabbro.
Mica-gabbro.
Diabase: structure diabase-granular (often ophitic).
Hornblende-diabase.
Pyroxene-diabase.
Diabase-porphyry: groundmass microcrystalline.
Basalt: structure microlitic or glassy.
Olivine-free basalt = *labradorite* Michel-Lévy.
Olivine-basalt.

PYROXENITE-PERIDOTITE FAMILY (pyroxene and olivine).

Peridotite (pyroxene and olivine).
Peridotite-porphyry.
Pyroxenite (pyroxene only).
Pyroxenite-porphyry.

In order to show with some exactness the range in chemical composition of the different rock families above indicated, there have been prepared tables of analyses, chiefly of rocks collected by the writer in the Sierra Nevada. These analyses are of fresh rocks, and were made chiefly in the laboratory of the United States Geological Survey by Messrs. Hillebrand, Stokes, and Steiger, whose record for accurate work is well known.

THE GRANITE FAMILY.

Since quartz or free silica and alkali feldspars, the most acid of the feldspars, are the chief constituents of the rocks of this family, it follows that it composes the most acid igneous rocks. The silica ranges from 66 to 76 per cent or more. In most cases the alkalis together amount to more than 6 per cent, and more than double the amount of lime. The iron oxides and magnesia are always low.

The macrocrystalline portion of the granite family may be divided into—

Granite, characterized by the granitic or hypidiomorphic structure. There is nearly always some soda-lime feldspar and mica and often hornblende present in addition to the quartz and alkali feldspar. The quartz and the alkali feldspar crystallize after the soda-lime feldspar and the ferromagnesian constituents.

Analyses of rocks of the granite family—Quartz-alkali feldspar.

	Granites.					Soda-granulites.				Potash-granulites.		Granite-porphyries.			Quartz-porphyries (rhyolite-porphyries).				Rhyolites.	
	No. 39 S. N. *a*	No. 303 S. N. *a*	No. 22 S. N. *a*	No. 372 S. N. *b*	No. 1485 S. N. *a*	No. 1523 S. N. *b*	No. 413 S. N. *a*	No. 725 S. N. *b*	No. 399 S. N., micro-pegmatite. *a*	No. 227 S. N. *a*	No. 161 S. N. *a*	No. 1639 S. N. *c*	No. 40 S. N. *a*	No. 565 S. N. *b*	No. 151 Amador. *a*	No. 553 Calaveras. *a*	No. 323 Plumas. *a*	No. 128 Plumas. *d*	No. 1675 S. N. *a*	No. 126 Amador. *a*
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
SiO_2	66.28	68.65	70.36	73.54	70.75	69.66	74.21	76.00	73.18	75.97	76.03	71.88	72.48	72.65	70.29	71.19	73.25	76.69	71.39	73.23
TiO_2	.54	.28	.20		.42		.30	.04	.25	.09	.07	.17	.28		.29	.35	Trace.		.17	.09
Al_2O_3	16.03	16.34	15.47		15.13		14.47	14.88	13.66	13.07	13.39	15.57	14.06		11.83	13.81	13.25		14.13	12.73
Cr_2O_3								None.		None.										
Fe_2O_3	1.80	.93	.98		.98		.35	.65	.21	.61	.48	1.07	.89		1.30	1.45			.63	.99
FeO	1.88	1.48	1.17		1.43		.50	.10	2.24	.39	.31	.30	1.05		2.08	1.68	1.74		.37	.16
MnO	.05	.08	Trace.		Trace.		None.	Trace	.07	*e* Trace	Trace.	None.	Trace.		.12	.07	Trace.		Trace.	Trace.
NiO					None.			None.		None.										
CaO	3.75	3.07	3.18	2.55	3.09	1.45	1.71	.19	2.10	1.49	1.28	2.03	2.17	1.94	2.30	2.87	2.23	.97	1.01	.61
SrO	Trace.	.07	Trace.		.04		Trace.	None.	Trace.	.03	Trace.	.08	Trace.		Trace?	Trace?	Trace?		Trace.	None.
BaO	.08	.09	.06		.12		None.	Trace.	.10	.14	.04	.02	.08		.07	.16	Trace.		.09	.02
MgO	1.12	1.29	.87		.73		.28	.06	.93	.14	.05	.68	.62		1.24	.74	.28	None.	.08	.22
K_2O	3.49	1.85	1.71	1.89	3.62	2.85	.10	2.77	2.72	5.62	5.18	1.80	4.75	1.61	3.05	1.82	3.79	2.75	5.69	5.17
Na_2O	4.10	4.85	4.91	4.46	3.05	4.49	7.62	3.52	3.70	2.51	2.98	5.81	3.30	4.92	2.68	4.24	2.69	2.81	2.89	1.91
Li_2O	Trace.	Trace.	Trace.		Trace.		Trace	None.	Trace.	*e* Trace	None.	None.	Trace.		None.	None.	Trace.		Trace.	Trace.
H_2O below 110° C	.03	.24	.06		.10		.15	.20	.10	.14	.15	.11	.16		.10	.11	.07		.42	.53
H_2O above 110° C	.41	.62	1.00		.51		.23	1.42	.57	.24	.34	.68	.35		1.35	.35	1.03		3.32	4.51
P_2O_5	.18	.15	.11		.10		.07	.11	.09	Trace	.03	.08	.09		.07	.09	Trace.		.03	.02
CO_2					None.			None.	.17	None.		None.			3.25		1.05			
Total	99.92	99.99	100.08		100.13		99.99	99.94	100.09	100.44	100.33	100.28	100.28		100.02	100.35	99.96		100.22	100.19
Sulphur					.03															

a Hillebrand, analyst. *b* Stokes, analyst. *c* Steiger, analyst. *d* Hillebrand and Steiger, analysts. *e* Faint.

Granulite or *aplite*, characterized by the granulitic structure, in which the quartz may show a tendency to idiomorphic development, but both the quartz and the alkali feldspar appear usually to have crystallized at the same time. Granulite occurs very abundantly in the Sierra Nevada as dikes, chiefly in granite and quartz-diorite. It may be regarded as representing the acid remainder in a granite or quartz-diorite magma after the more basic elements have crystallized, and it will be noted that it is composed of the two elements that are the last to crystallize in the ordinary granites and quartz diorites, namely, quartz and alkali feldspar. At a late period, after the main mass of the granitoid rock has crystallized, the granulite is forced up from below and fills previously formed cracks, which are perhaps the result of cooling. Viewed in this light, evidently granulites stand in a genetic relation to the more basic granites, with which, in the Sierra Nevada, they are mostly directly associated.

Pegmatites, as is well known, are closely related in composition and origin to some granulites. The granulitic structure and the pegmatoid or micropegmatoid structure are often to be seen in the same granulite dike.

The microcrystalline granites are usually porphyritic, and have been chiefly called granite-porphyries. In some cases where there are no phenocrysts, but the rock is even-grained, it may be called a microgranite, or, indeed, this term may with much reason be given to all the microcrystalline granites, whether porphyritic or not. It should be noted, however, that the term "microgranite" as now in use would not coincide with the above defintion. On Pl. XLI *A*, the photomicrograph of No. 40 S. N. shows the structure of a typical granite-porphyry.

The cryptocrystalline granites include quartz-porphyry (rhyolite-porphyry), restricting this term to those porphyritic rocks in which the groundmass is essentially crystalline, without any reference to age, and the "porphyries à quartz globulaire," as Michel-Lévy calls them. An example of this latter rock is represented in the photomicrograph of No. 247 Amador, Pl. XLI B. The cryptocrystalline granites may occur as dikes, but appear chiefly to form the deeper-seated portions of surface flows.

The fourth structural type, the glassy, is represented by the rhyolites proper (in which glass forms a groundmass wherein phenocrysts of sanidine, mica, and sometimes other minerals are developed), rhyolitic glass or true obsidian, and pumice. Such rocks probably are always the product of rapid cooling, and may always be regarded as eminently surface lavas. While rhyolites are generally considered as the effusive form of the granite magma, it is evident from the composition that those from the Sierra Nevada are not so closely related to the granites of the Sierra Nevada as to the granulites.

Localities of rocks of the granite family referred to in the table of analyses.

No. 39 S. N. Porphyritic granite. Mount Dana area. One-fourth mile northeast of Lake Tenaya.

No. 303 S. N. Biotite-granite. Downieville area. Indian Valley.

No. 22 S. N. Soda-granite. Bidwell Bar area. North side of the Middle Feather, opposite Enterprise.

No. 372 S. N. Granite. Mariposa area. Granite quarry near Raymond.

No. 1485 S. N. Biotite-granite. Big Trees area. Canyon of the North Tuolumne, associated with the gneiss series.

No. 1523 S. N. Soda-granulite. Sonora area. Dike east of Moccasin Creek.

No. 413 S. N. Soda-granite. Merced area. About 5 miles west of the town of Mariposa.

No. 725 S. N. Soda-granulite. Bidwell Bar area. Dike in the serpentine of Grizzly Hill.

No. 399 S. N. Micropegmatite. Merced area. Bank of Agua Fria Creek; part of the same area as No. 413.

No. 227 S. N. Granulite. Downieville area. Dike in quartz-mica-diorite east of Milton.

No. 161 S. N. Granulite. Downieville area. Dike in quartz-mica-diorite about 7 miles nearly east of the Sierra Buttes.

No. 1639 S. N. Soda-granite-porphyry. Sonora area. South side of the Merced River, a little downstream from the mouth of the North Fork.

No. 40 S. N. Granite-porphyry. Mount Dana area. A little west of Lake Tenaya.

No. 565 S. N. Soda-granulite. Bidwell Bar area. Big Bend of the North Feather.

No. 151 Amador. Quartz-porphyry. Jackson area. Streak in the amphibolite-schist.

No. 553 Calaveras. Quartz-porphyry. Jackson area. One and one-half miles northeast of Milton.

No. 323 Plumas. Quartz-porphyry. Downieville area. Grizzly Mountains.

No. 128 Plumas. Quartz-porphyry schist. Downieville area. Ridge just southwest of Bunker Hill.

No. 1675 S. N. Rhyolite. Downieville area. Two and one-half miles east of Penman Peak.

No. 126 Amador. Rhyolite. Jackson area. Butte just south of Buena Vista Peak.

THE QUARTZ-DIORITE FAMILY.

The macrocrystalline portion of the quartz-diorite family shows the hypidiomorphic structure to perfection. Intermediate soda-lime feldspars and quartz are the essential constituents, and ferro-magnesian elements, with a variable amount of alkali feldspar, are usually present. The quartz is nearly always interstitial, but in some cases quartz grains are distinctly inclosed in the alkali feldspar. The quartz-mica-diorite No. 691 S. N., of which a photomicrograph is represented on Pl. XLII, is more basic than normal, the soda-lime feldspar varying from oligoclase to basic labradorite, but it illustrates well the granite structure of the quartz-diorites, which, indeed, grade over into hornblende granites.

The quartz-diorite-porphyries are very similar to the granite-porphyries in structure. (See Pl. XLIV, B.)

Analyses of rocks of the quartz-diorite family—Oligoclase-andesine and quartz.

	Basic quartz-diorites.				Quartz-mica-diorites (granodiorites).						Quartz-diorite-porphyries.	
	No. 1495 S. N. *a*	No. 225 S. N. *a*	No 936 S. N. *a*	No. 691 S. N. *b*	No. 345 Plumas. *c*	No. 369 S. N. *a*	No. 17 S. N. *a*	El Capitan. *d*	No. 71 S. N. *a*	No. 1490 S. N. *a*	No. 304 S. N. *a*	No. 1689 S. N. *c*
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	55.86	57.26	57.80	59.68	59.83	62.62	63.43	66.40	67.33	69.66	66.65	72.24
TiO_2	1.20	.53	.70	.65		.55	.73		.36	.21	.33	.41
Al_2O_3	19.30	16.51	16.43	17.09		17.51	14.20	17.13	15.93	17.57	17.61	13.85
Cr_2O_3		None.	None.	None.								
Fe_2O_3	.91	3.27	1.62	2.85		.49	1.54		1.90	.21	.93	1.45
FeO	4.78	5.19	6.51	2.75		4.06	4.56	3.77	1.59	1.04	1.67	1.86
MnO	.16	.18	.18	Trace.		.05	.03	.30	.09	Trace.	.07	.12
NiO	Trace.	Trace?	.03	None.						None.		
CaO	7.31	6.69	7.21	6.62	6.49	5.49	5.51	4.05	4.09	4.54	4.44	3.40
SrO	.04	.06	Trace?	Trace.		Trace.	Trace.		Trace.	.05		Trace.
BaO	.13	.10	.09	.04		Trace.	.06		.08	.03	.12	.08
MgO	2.94	3.41	4.14	3.54		2.84	2.35	.97	1.63	.58	1.26	1.10
K_2O	1.52	2.93	2.29	1.31	1.69	1.76	2.19	2.08	2.46	.71	1.70	.39
Na_2O	3.52	2.65	2.35	3.87	3.53	3.49	3.49	4.49	3.76	4.91	4.59	4.43
Li_2O	Trace.	Trace.	Trace.	Trace.		Trace.	None.		Trace.	None.	Trace.	None.
H_2O below 110° C	.19	.20	.11	.15		.22	.15		.19	.05	.03	.17
H_2O above 110° C	1.23	.95	.38	1.00		.92	1.50		.66	.50	.41	.69
P_2O_5	.38	.30	.19	.25		.12	.11		.11	.03	.18	.10
CO_2	None.	None.	None.	.20						None.		
FeS_2	.39			None.						Trace?		
SO_3				Trace.								
Cl				.03								
F				None.								
Total	99.86	100.23	100.03	100.03		100.12	99.85		100.18	100.09	99.99	100.29
Sulphur	.21									Trace?		

a Hillebrand, analyst. *b* Stokes, analyst. *c* Hillebrand and Steiger, analysts. *d* Drown, analyst.

Dacite-porphyries with a cryptocrystalline groundmass are very abundant in the Sierra Nevada, if we reckon here, as seems logical, the altered quartz-bearing andesites (quartz-porphyrites, Rosenbusch) which are shown on the various folios already issued. The rocks of the Sierra Buttes ridge, although some of these approach in composition the quartz-porphyries, would perhaps be placed here by some authors. Especial attention is called to the fact that nearly all the rocks called quartz-porphyrites on the Jackson and Placerville folios and in the writer's paper in the Fourteenth Annual Report are altered dacites or dacite-porphyries.

Dacites with a glassy groundmass have not certainly been recognized by the writer in the Sierra Nevada, unless we place here the acid andesites like 209 S. N. (table of diorite analyses) or 350 Plumas County,[1] the silica content of each of which is over 66 per cent, arguing that no rock chiefly oligoclase can contain so much silica without free quartz being present. The same would apply to the apo-andesite or apo-dacite (porphyrite), No. 25 S. N., in which no quartz was determined by the use of the microscope. Indeed, if the analyses of these three rocks and of No. 1829 Cascade Range, in all of which no quartz has been detected, be compared with analyses of undoubted dacites they will be seen to closely correspond. It is more than probable that many of the rocks mapped as quartz-porphyrites were originally dacites; that is to say, they may have had more or less glass in the groundmass, which has been devitrified. The writer has not been able, however, to find any criteria by which it can in many cases be determined whether a finely granular groundmass represents a devitrified glass or was originally crystalline, although recognizing that there are instances when the original glassy nature of the rock is beyond question.

Localities of rocks of the quartz-diorite family referred to in the table of analyses.

No. 1495 S. N. Quartz-diorite. Big Trees area. Bed of Bear Creek. Basic facies near contact with the gneiss series.

No. 225 S. N. Quartz-mica-diorite. Downieville area. East of Milton.

No. 936 S. N. Quartz-pyroxene-diorite. Sonora area. About 1½ miles southeast of Sonora.

No. 691 S. N. Quartz-mica-diorite. Bidwell Bar area. About 1½ miles southwest of Merrimac.

No. 345 Plumas. Quartz-mica-diorite. Downieville area. One and three-tenths miles northeast of Penman Peak.

No. 369 S. N. Quartz-mica-diorite. Mariposa area. Chowchilla River.

No. 17 S. N. Quartz-mica-diorite. Smartsville area. Two miles northeast of Bangor.

El Capitan. Granodiorite or quartz-mica-diorite. Yosemite Valley. Taken from Fortieth Parallel Survey reports.

No. 71 S. N. Granodiorite or quartz-mica-diorite. Downieville area. Southwest base of Mount Ingalls.

No. 1490 S. N. Quartz-diorite. Big Trees area. Bed of Bear Creek at contact of granodiorite and gneiss series. Dike cutting both of these rocks.

No. 304 S. N. Quartz-diorite-porphyry. Downieville area. Dike in the granite of Indian Valley.

No. 1689 S. N. Quartz-diorite-porphyry. Jackson area. Southeast of Milton and north of Rock Creek.

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, p. 490.

THE SYENITE FAMILY.

The syenite family may be designated as that group of igneous rocks composed chiefly of alkali feldspars; that is to say, of orthoclase, microcline, anorthoclase, and albite. Quartz and soda-lime feldspars are often present in small amount, and there are usually ferromagnesian elements in these rocks. The most acid feldspar of the group, albite, when pure, contains 68 per cent of silica; hence, in a rock composed entirely of albite the silica content may reach 68 per cent. This is nearly realized in soda-syenite porphyry, No. 1521 S. N., and in a porphyry from the Coast Ranges, No. 76 Knoxville[1] collection, and also in 455 Plumas.

The augite-syenite No. 30 is a pebble from a Carboniferous conglomerate in Amador County, Cal. Idiomorphic augite and plagioclase are inclosed in later orthoclase, which is quite fresh. Leucoxene from ilmenite is present also in the orthoclase. No. 165 S. N. has been called an augite-syenite,[2] but the soda-lime feldspars are in too large amount for even an augite-syenite of the monzoni type, and therefore No. 165 is here placed with the pyroxene-diorites. (See table of analyses of quartz-diorites.) Mr. W. Lindgren[3] has, however, found a rock that may be called monzonite, near Nevada City.

In the description of the Downieville area a dike of pyroxene-syenite (No. 284 S. N.) is noted, and also one in the description of the Sonora area (No. 950 S. N.).

Hornblende-syenite.—In 1893 Prof. C. D. Walcott brought back from Deep Spring Valley, in Inyo County, a gray, rather coarse-grained granitoid rock, which was given to Mr. J. S. Diller for determination, and was by him referred to the writer, as being the one most interested in the region in question. This rock proved to be hornblende-syenite. A partial analysis (No. 882 S. N.) is given in the table. It is composed of orthoclase, microcline, plagioclase, green hornblende, titanite, apatite, and a little quartz. According to Dr. Oscar Loew,[4] syenite is found intrusive in Silurian limestone near Cerro Gordo. He states that the syenite is made up of oligoclase, orthoclase, hornblende, and a little quartz. There is also an area of hornblende-syenite in the northwest portion of the Big Trees area.

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[1] No. 76 Knox. is a pebble from a Cretaceous conglomerate near Knoxville, Napa County, Cal. See Mon. U. S. Geol. Survey, Vol. XIII, p. 144. Examination with the microscope shows it to be chiefly or entirely feldspar, and the composition makes it certain that the feldspar is chiefly albite.

[2] Jour. of Geology, Vol. III, 1895, p. 390, and Am. Geologist, June, 1896.

[3] The gold-quartz veins of Nevada City and Grass Valley districts: Seventeenth Ann. Rept. U. S. Geol. Survey, Part II.

[4] Ann. Rept. Wheeler Survey, 1876, p. 63.

Analyses of rocks of the syenite family—Alkali feldspars.

	No. 30 Amador, augite-syenite. *a*	No. 882 S. N., hornblende-syenite. *b*	No. 455 Plumas, soda-syenite. *c*	Soda-syenite porphyries.				Orthophyre (apo-? trachyte) tuff.		No. 36 S. N., Table Mountain basalt. *c*	Trachytes.		Tuff-like trachytes.	
				No. 452 S. N. *d*	No. 1522 S. N. *a*	No. 1521 S. N. *a*	No. 76 Knox. *e*	No. 219 Plumas. *d*	No. 352 Plumas. *d*		From Bolsena. *f*	No. 86 Tuol. *b*	No. 85 Tuol. *b*	No. 1420 S. N. *c*
	Per cent.	*Per cent.*	*Per cent*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	55.45	59.48	66.54		66.81	67.53	68.80	53.98	55.29	56.19	57.97	59.88	61.09	62.33
TiO_2						.07				.69				1.05
Al_2O_3				*g* 20.00		18.57				16.76	17.65			17.31
Fe_2O_3						1.13				3.05	.63			3.00
FeO						.08				4.18	7.50			1.63
MnO						Trace.				.10	.09			.08
CaO		5.94	.43	.49	1.03	.55		2.78	3.08	6.53	5.53	5.09	4.94	3.23
SrO						Trace.				*h* Trace.				.05
BaO						None.				.19				.24
MgO	4.11		.77			.24				3.79	1.71			1.65
K_2O	5.18	5.75	.89	1.15	.07	.10	0.91	4.88	5.58	4.46	5.31	5.06	5.27	4.46
Na_2O	1.73	4.62	10.28	8.72	11.18	11.50	10.02	5.03	4.65	2.53	1.50	3.90	3.69	4.21
Li_2O						None.				Trace.				Trace.
H_2O below 110° C						.15				.34				.44
H_2O above 110° C						.31				.66				.75
P_2O_5						.11				.55				.29
CO_2														None.
FeS_2														.06
Fluorine						Trace.								
ZrO_2														.04
Carbon														.11
Total						100.34				100.02				100.33
Sulphur														.03

a Stokes, analyst. *b* Fireman, analyst. *c* Hillebrand, analyst. *d* Steiger, analyst. *e* Melville, analyst. *f* Klein (?), analyst. *g* About. *h* Strong.

Soda-syenite.—In the writer's former report[1] on the Sierra Nevada, record was made of the occurrence of white dikes in the serpentine near Meadow Valley, Plumas County. Some of these dikes are composed of coarsely granular albite only (see No. 455 Plumas, in the table of analyses). Such a rock may be called an albitite. Other dikes in the immediate neighborhood of the albitite dikes contain quartz in addition to the feldspar, forming a soda-granulite, as the term is used by Michel-Lévy, or a soda aplite, following Rosenbusch.

Soda-syenite and soda-syenite-porphyry dikes occur also in Tuolumne County, along the Mother lode, and some notes concerning them are published in the description of the Sonora area.

In the Sierra Nevada soda-syenite-porphyries occur entirely as dikes so far as known. The microcrystalline nature of the groundmass and the porphyritic feldspars are well seen in the photomicrograph of No. 46 Tuolumne, Pl. XLIII. These soda-feldspar dikes appear to be often associated with gold deposits, and some notes illustrating this association may be found in the American Geologist for June, 1896, and in the description of the Sonora district.

The rock described by Dr. Charles Palache[2] as containing a blue soda-hornblende, called by him crossite, appears to be very similar in mineral and chemical composition to some of the soda syenite dikes collected in the Sonora area. Dr. Palache's material came from a bowlder in the coast ranges near Berkeley, but was presumed to be of local origin. It may have come from a dike in the neighborhood.

In this connection it is interesting to note that Dr. F. L. Ransome[3] found granular masses of albite feldspar in the contact zones of glaucophane-schists about serpentine and fourchite areas on Angel Island. The association of a soda-feldspar and a schist composed of a soda-hornblende is suggestive of a genetic connection. Although Mr. Ransome did not regard the masses of soda-feldspar as representing igneous material, the known occurrence of these soda-feldspar dikes in and near serpentine suggests that these albite masses on Angel Island are in reality portions of igneous dikes. That such dikes exist in the coast ranges is beyond question.

As above noted, pebbles of a soda-feldspar-porphyry are found in the Cretaceous at Knoxville, and Mr. H. W. Fairbanks, in a remarkably interesting paper on the geology of Point Sal,[4] notes the occurrence of white dikes cutting the serpentine at Point Sal, in the northwest portion of Santa Barbara. The feldspar was not determined, but the facts given by Mr. Fairbanks about it do not preclude its being albite.

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[1] Rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, p. 477.

[2] Bull. Dept. of Geol., Univ. of Cal., vol. 1, p. 182.

[3] Geology of Angel Island: Bull. Dept. of Geol., Univ. of Cal., vol. 1, p. 211.

[4] Bull. Dept. of Geol., Univ. of Cal., vol. 2, No. 1, 896, pp. 1-91.

The contact zones of glaucophane-schist on Angel Island, described by Ransome, consist in part of schist made up almost entirely of glaucophane. It is certainly difficult to understand the formation of such a rock from a sandstone or shale without the addition of material not originally in these rocks. The occurrence of glaucophane needles in certain sedimentary rocks, as noted by Ransome, does not prove that those masses composed chiefly of glaucophane were derived from a clastic rock. If it be supposed that the glaucophane-schists are in part built up of the material of soda-feldspar dikes, it is evident that they do not represent a contact-metamorphic phenomenon, for the dikes are, at all points known, later than the serpentine. The singular manner in which these dikes are intruded along the contact of the serpentine and the adjacent sedimentary masses to the southeast of Coulterville, as noted in the description of the Sonora area, offers a plausible explanation of the origin of the streaks of glaucophane-schist on Angel Island. The writer merely offers the above as suggestive of the advisability of a reexamination of the subject of the origin of glaucophane-schist in the Coast Ranges. Dr. Ransome's careful work throws the burden of the doubt on the new hypothesis.

Pre-Cretaceous surface or volcanic rocks of the syenite family or trachytes are known in the Sierra Nevada only in Plumas County, where they occur as tuffs in the Robinson formation (Upper Carboniferous). These are further mentioned in the description of the Downieville area. Such rocks may be called orthophyre-tuffs, or, when devitrified, apotrachyte tuffs.

Tertiary trachytes are known thus far only in the area of the Big Trees sheet. They occur both as tuffs (?) and massive flows, the latter strongly resembling basalt in macroscopic appearance. They are placed with the trachytes chiefly on the basis of their chemical composition. Indeed, the Tuolumne Table Mountain basalt has so high an alkali content that it is placed in the table with the trachytes for comparison. This flow can be traced from Knights Ferry, in Stanislaus County, across the Sonora area into the Big Trees district, not far from where specimens 85 and 86 Tuolumne were collected.

As the writer has only cursorily examined these trachytes, the matter of their classification will not be further considered at present.

No. 1420 S. N. is a tuff-like trachyte from an area 3¾ miles southwest of Clover Meadow, Tuolumne County. Included in this fragmental-looking lava there are sometimes minute, glassy, black particles resembling lignite, and these are presumably responsible for the carbon shown in the analysis.

The analysis of the trachyte from Bolsena is taken from Zirkel's Petrography, 1893, Vol. II, p. 378. It shows more lime and less silica than most of the analyses given by Zirkel.

THE DIORITE FAMILY.

Since oligoclase is the most acid constituent of this group (except accessory quartz, etc.), the highest silicia content of a diorite or andesite should not often exceed 63 per cent. As a matter of fact, three of the analyses given, Nos. 209, 1829, and 25, show more than 66 per cent of silica. It is more than probable that these rocks contain free silica, although its presence has not been microscopically demonstrated, and that they properly belong with the dacites in the quartz-diorite family.

The term andesite-porphyry, not having been much used,[1] needs some explanation. No. 16 in the table of analyses is called an andesite-porphyry. The groundmass of this rock is fine granular (cryptocrystalline), and this is an original structure and not the result of devitrification. The writer would not call, at present at least, a porphyritic-andesite an andesite-porphyry if the groundmass was undoubtedly glassy.

The diorites with idiomorphic hornblende, in part diorite-porphyries, would be called in part diorite-porphyrite by Rosenbusch. In some cases in the same rock mass the hornblende occurs as phenocrysts only—that is, in only one generation—and again in two generations. The latter facies would be called lamprophyric by Rosenbusch,[2] and rocks of this character, chiefly more basic than the diorites here referred to, he places in one group. Fig. I of Pl. XLIV, diorite-porphyry, No. 298 S. N., shows the structure imperfectly. Often the groundmass is fine granular. In a recent paper[3] Mr. W. D. Matthew describes and figures a diorite-porphyrite which in structure and mineral composition corresponds almost exactly to the diorite-porphyries of the Sierra Nevada, the chief difference being that much of the feldspar in the New Brunswick rocks is labradorite, and consequently they are more basic than the rocks here noted. As Mr. Matthew states, his rock may be called a camptonite.

The New Brunswick diorite-porphyries are dikes in rocks referred to the Laurentian. Mr. Matthew says: "They are singularly like the basic segregations in the granite, which latter they cut in several places, and are perhaps to be connected with it as the last member of the intruded series, injected after the rest had solidified."

In the Sierra Nevada, diorite-porphyry occurs almost solely as dikes; the only mass known to the writer that can be called an area is shown on the Jackson geologic map 2 miles northwest of Volcano, and is a mile in length.

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[1] It is used in the text of the Three Forks folio, No. 24, of the Geologic Atlas of the United States.
[2] Massige Gesteine, 1895, p. 388.
[3] The effusive and dike rocks near St. John, N. B.: Trans. N. Y. Acad Sci., Vol. XIV, p. 210.

Analyses of rocks of the diorite family—Oligoclase-andesine feldspars.

				Diorites with idiomorphic hornblende.							Hornblende-pyroxene-andesites.				Hypersthene-andesites.			
	Acid oligoclase Ab: An:: 4:1.	Basic andesine Ab: An:: 1:1.	No. 534 S. N., uralite-diorite. *a*	No. 938 S. N., basic diorite. *b*	No. 817 S. N. *b*	No. 1655 S. N. *b*	No. 935 S. N. *b*	No. 466 Ps. *a*	No. 1481 S. N. *b*	No. 16 S. N., hornblende-andesite porphyry. *b*	No. 69 Plumas. *b*	No. 72 S. N. *b*	No. 262 S. N. *b*	No. 123 Plumas *b*	No. 661 S. N. *b*	No. 209 S. N. *b*	No. 1829 Lassen Peak.	No. 25 S. N., apo-andesite or porphyrite. *c*
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
SiO_2	63.3	55.6	51.07	53.46	54.64	57.87	58.05	59.61	55.18	60.20	57.32	58.47	59.34	60.00	56.88	66.94	68.12	68.58
TiO_2			1.65	.70	.61	.53	.72		.83	.57		.51	.32		.45	.30	.25	.57
Al_2O_3	23.1	28.3	14.93	} 14.81	12.09	{ 16.30	15.46		17.35	17.21		18.80	17.61		18.25	16.49	16.24	13.04
Cr_2O_3			None.				None.								None.		None.	
Fe_2O_3			6.44	2.60	1.81	1.71	1.69		2.77	3.12		3.34	3.63		2.35	1.41	1.26	.26
FeO			5.98	5.15	5.03	3.86	5.09		3.90	2.69		2.64	2.28		4.43	1.87	2.08	3.40
MnO			.22	.18	.13	.08	.14		.15	.12		.13	.12		.18	.13	.10	.15
NiO			None.	.05	.05		None.		03						*d*Trace.			
CaO	4.2	10.4	7.89	8.44	7.74	5.53	6.94		7.98	6.04	7.13	6.60	6.45	6.33	7.53	4.77	3.80	3.22
SrO			None.	Trace.	Trace.	Trace.	Trace.		.06	Trace.		.05	.04		.04	.05	.02	*e*Trace.
BaO			None.	.05	.05	.05	.07		.04	.11		.09	.11		.11	.07	.09	.10
MgO			4.84	7.27	11.86	5.50	4.84		4.80	3.18		2.69	3.50		4.07	1.98	1.35	1.01
K_2O			.16	1.30	1.01	.75	2.14	1.31	1.42	1.44	1.35	2.01	1.94	1.71	1.42	1.65	2.54	1.90
Na_2O	9.4	5.7	5.04	2.64	2.35	5.01	2.86	3.58	3.42	3.35	3.98	3.58	3.40	3.62	3.29	3.88	3.89	4.94
Li_2O			None.	Trace.	Trace.	Trace.	Trace.		Trace.	Trace.		Trace.	Trace.		*d*Trace.	Trace.	Trace.	None.
H_2O below 110° C			.24	.12	.12	.26	.10		.16	1.12		.14	.64		.24	.35		.16
H_2O above 110° C			1.73	2.13	2.44	2.40	2.02		1.52	1.18		.92	.74		.50	.22	.40	1.00
P_2O_5			.19	.16	Trace.	.27	.16		.20	.17		.22	.25		.30	.12	.14	.20
CO_2			None.	.44	None.		None.								None.			1.31
FeS_2			None.	.26	None.		None.											.15
Total			100.38	99.76	100.01	100.12	100.28		100.09	100.50		100.19	100.37		100.06	100.23	100.28	99.99
Sulphur									.15									

a Stokes, analyst. *b* Hillebrand, analyst. *c* Hillebrand and Steiger, analysts. *d* Faint. *e* Strong.

It is not a little singular that these dikes, usually but a few inches in width, should be found over the entire length of the Sierra Nevada, so far as surveyed, and yet form scarcely any areas large enough to be put on the maps. It can hardly be supposed that a huge batholite of this material underlies the Sierra Nevada, only a small amount of which has been squeezed up in cracks forming the dikes. It seems much more likely that the diorite magma is a differentiation product, perhaps of the quartz-diorite, and that it nowhere forms a reservoir of any size. It may indeed be compared in this respect with the potash-granulite dikes, which the writer regards as a differentiation product of a granite or quartz diorite magma. It is not impossible that in these diorite-porphyries and the potash-granulites we have an example of "complementary"[1] rocks, as Brögger uses the term.

While the writer would not regard this as more than possible at present, it may be seen that the average composition of one of the diorite-porphyries and a granulite is strikingly similar to the composition of a granodiorite, as is shown by the following analyses:

Analyses of complementary (?) rocks.

	No. 1481, diorite porphyry.	No. 227, granulite.	Average of Nos. 1481 and 227.	No. 71, granodiorite.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Silica	55.18	75.97	65.57	67.33
Alumina	17.35	13.09	15.22	15.93
Lime	7.98	1.49	4.73	4.09
Magnesia	4.80	.11	2.47	1.63
Potassa	1.42	5.62	3.52	2.46
Soda	3.42	2.51	2.96	3.76

It is evident, however, that such a comparison as instituted above, to have much value, should be based on the average composition of the diorite-porphyries, granulites, and granodiorites, deduced from a series of analyses of each of these rocks.

Localities of the rocks of the diorite family given in the table of analyses.

No. 534 S. N. Uralite-diorite. Bidwell Bar area. Forbestown Ridge.
No. 938 S. N. Diorite-porphyry. Sonora area. Dike in quartz-pyroxene-diorite.
No. 817 S. N. Diorite. Bidwell bar area. Dike (?) in quartz-mica-diorite.
No. 1655 S. N. Diorite. Smartsville area. Dike in quartz-diorite.
No. 935 S. N. Diorite-porphyry. Sonora area. Dike in quartz-pyroxene-diorite.
No. 466 Plumas. Diorite-porphyry. Bidwell Bar area. Dike in quartz-mica-diorite.
No. 1481 S. N. Diorite-porphyry. Big Trees area. Dike in the gneiss series of the North Tuolumne.
No. 16 S. N. Andesite-porphyry. Downieville area. Part of a massive flow.
No. 69 Plumas. Andesite. Downieville area. Bowlder in the andesite-breccia.

[1] See definition in glossary at the end of this chapter.

No. 72 S. N. Andesite. Downieville area. Bowlder in the andesite-breccia.
No. 262 S. N. Andesite. Downieville area. Large dike southeast of Poker Flat.
No. 123 Plumas. Andesite. Downieville area. Two and four-tenths miles southwest of Eureka Peak.
No. 661 S. N. Hypersthene-andesite. Bidwell Bar area. Top of Franklin Hill.
No. 209 S. N. Hypersthene-andesite. Downieville area. High point northeast of Goodyears Bar.
No. 1829 Cascade Range. From Lassen Peak. J. S. Diller.
No. 25 S. N. Old andesite or dacite-porphyry. Placerville area. Southwest of Latrobe.

THE GABBRO FAMILY.

Since the two prominent constituents of the gabbro family, basic feldspar and a metasilicate, usually augite, do not contain more than 54 per cent of silica, most rocks properly referable to this group will usually contain less than 54 per cent of silica, as there are generally more basic elements present.

The single analysis in the table (No. 36) that shows a higher silica content is of a peculiar basaltic rock, as noted under the syenite family. The amount of alkali is so large that it may be almost regarded as an abnormal trachyte. (See description of trachytes under the head of Big Trees area.)

Localities of rocks of the gabbro family of which analyses are given in the table.

No. 892 S. N. Orbicular gabbro. Downieville area. One mile east of Penman Peak.
No. 705 S. N. Gabbro. Bidwell Bar area. Bucks Mountain.
No. 158 Plumas. Gabbro. Downieville area. East slope of Eureka Peak.
No. 446 S. N. Diabase. Sonora area. Northeast of Hornitos. Dike in sedimentary schists.
No. 226 S. N. Diabase-porphyry. Downieville area. Dike in quartz-mica-diorite.
No. 26 S. N. Melaphyre tuff. Jackson area. West of Jackson.
No. 19 S. N. Pre-Cretaceous tuff. Smartsville area. Near Honcut Creek.
No. 276 Plumas. Older basalt. Downieville area. Near Red Clover Valley.
No. 18 S. N. Older basalt. Chico area. Oroville Table Mountain.
No. 314 and 311 Plumas. Dolerite. Downieville area. Mount Ingalls.
No. 667 S. N. Late basalt. Bidwell Bar area. One and one-half miles west of Franklin Hill.
No. 36 S. N. Table Mountain basalt. Sonora area. Tuolumne Table Mountain.

THE PERIDOTITE FAMILY.

This group of rocks is made up chiefly of ferromagnesian minerals, with certain accessory elements, such as magnetite and chromite. The dominant characteristic from a chemical standpoint may be said to be the high magnesia content. In the table of analyses the composition of the main component minerals is given to enable the reader to judge of the necessarily basic nature of the rocks of this family.

The analysis of the olivine is taken from Kalkowsky's Elements of Lithology, p. 236.

The analysis of the diallage is copied from Dana's Mineralogy, 1892, analysis 53, p. 360. This diallage came from the Balta Islands, Scotland. It contains 4.17 per cent of H_2O, in addition to the constituents given in the table.

Analyses of rocks of the gabbro family—Labradorite-anorthite feldspar.

	Acid labradorite Ab:An::3:4.	Basic anorthite Ab:An::0:1.	Gabbro.			No. 446 S. N., diabase. *c*	No. 226 S. N., diabase-porphyry. *c*	Altered basalt (melaphyre).		Older basalt.		Dolerite.		No. 667 S. N., fine-grained basalt. *a*	No. 36 S. N., Table Mountain basalt. *c*
			No. 892 S. N. *a*	No. 705 S. N. *a*	No. 158 Plumas. *b*			No. 26 S. N. *c*	No. 19 S. N. *c*	No. 276 Plumas. *c*.	No. 18 S. N. *c*	No. 314 Plumas. *c*	No. 311 Plumas. *c*		
	Per cent.	*Per cent.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*
SiO_2	53.7	43.2	45.92	50.56	53.14	51.32	51.27	49.24	54.66	50.56	50.66	52.81	53.91	51.21	56.19
TiO_2						1.23	.60	.96	.67	1.71	2.39	.84	.52	.31	.69
Al_2O_3	29.6	36.7				15.28	} 12.14	{ 14.79	15.85	14.13	13.97	16.60	17.95	17.59	16.76
Cr_2O_3															
Fe_2O_3						.47	2.51	1.52	1.82	3.54	2.55	2.66	2.21	4.71	3.05
FeO						8.59	6.71	8.00	5.12	8.90	10.20	6.13	4.80	4.42	4.18
MnO							.04	.18	.18	.13	.29	(*d*)	.10	Trace.	.10
NiO						.16	.24				Trace.				
CaO	11.08	20.1	9.61	14.64	9.56	11.58	10.32	10.74	8.75	7.58	8.08	10.14	10.40	10.36	6.53
SrO						*e* Trace.	Trace?	Trace.	Trace.	Trace?	Trace.	Trace.	Trace.		*f* Trace.
BaO						None.	.07	.04	.04	.25	.22	.03	.05	None.	.19
MgO			13.85		4.97	7.25	10.88	6.89	5.64	4.07	4.45	6.12	5.52	7.12	3.79
K_2O			.10	.34	1.54	.22	1.63	.88	.47	2.10	1.95	1.05	1.34	.91	4.46
Na_2O	4.09	None.	.71	2.08	1.75	2.92	2.00	2.76	3.46	2.94	3.32	2.79	2.90	2.49	2.53
Li_2O						*e* Trace.	Trace.	Trace.	None.	Trace?	None.	Trace.	Trace.	None.	Trace.
H_2O below 110° C						.06	.17	.20	.25	1.06	.27	.38	.20	.58	.34
H_2O above 110° C						.95	1.16	2.97	2.48	1.12	.43	.54	.20	1.07	.66
P_2O_5						.25	.21	.17	.15	1.14	1.01	.23	.21	.09	.55
CO_2							None.	.90	.39					None.	
FeS_2							None.		.09						
Total						100.28	99.92	100.08	100.02	99.81	99.81	100.32	100.31	100.86	100.02

a Steiger, analyst. *b* Hillebrand and Steiger, analysts. *c* Hillebrand, analyst. *d* Undetermined. *e* Faint. *f* Strong.

The analysis of the hypersthene is from a paper by Hague and Iddings.[1]

The analysis of the enstatite, by Breidenbaugh,[2] is of a specimen from the Tilly Foster iron mine, Maine.

The silica content of this group is not likely to rise above 54 per cent or to fall below 40 per cent, except with a rock composed entirely of olivine, with a considerable amount of iron ore. By the addition of feldspar, usually anorthite or labradorite, the peridotites grade into gabbros.

No effusive rocks that can be assigned to this group have certainly been detected in the Sierra Nevada.

The serpentines, Nos. 176 and 181, are not from the Sierra Nevada, but were collected by the writer in Bagley Canyon, on the north slope of Mount Diablo, and the pyroxenite, No. 242, from the northeast slope of Mount Diablo.[3]

Serpentines or peridotites, Nos. 302 and 325, are from the north end of the range, in Butte and Plumas counties.

Analyses of rocks of the peridotite family—Pyroxene-olivine.

	Olivine. *a*	Diallage. *b*	Hypersthene. *c*	Enstatite. *d*	Serpentines. No. 176 Mt. D. *e*	No. 302 S. N. *f*	No. 181 Mt. D. *e*	No. 325 S. N. *g*	No. 242 Mt. D., pyroxenite. *e*	No. 416 S. N. *g*
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
SiO_2	40.05	50.23	50.33	54.17	36.57	38.94	40.50	44.81	53.25	47.75
TiO_2	.07	....	....	....	....	....	....	} 1.88	....	.37
Al_2O_3	.39	5.85	.97	3.30	.95	....	.78		2.80	10.56
Cr_2O_3	.24	....	....	....	.33	....	.41	.29	.54	.24
Fe_2O_3	2.36	....	22.00	9.94	7.29	9.96	4.01	1.98	.69	.74
FeO	7.14	5.22	....	....	.37	....	2.04	4.52	5.93	8.34
MnO	.20	....	.64	.24	.10	....	.13	.13	.09	.10
NiO	....	....	....	....	.31	....	.11	.09	.07	.07
CaO	1.16	11.23	1.88	....	.14	.11	.39	6.58	16.22	9.62
SrO	....	....	....	....	....	....	....	None.	....	Trace.
BaO	....	....	....	....	....	....	....	None.	....	None.
MgO	48.68	21.59	23.29	31.99	40.27	39.71	37.43	30.91	19.91	19.09
K_2O	.21	1.20	....	} .99	Trace.	....	.16		Trace.	.12
Na_2O	.08	.58	....		.31	....	.28	} .15	.19	1.32
Li_2O	....	....	....	....	....	....	....		....	Trace.
H_2O below 110° C.	.14	....	....	....	.94	....	2.81	.15	.05	.05
H_2O above 110° C.	.66	....	....	....	12.43	....	10.94	6.88	.24	2.06
P_2O_5	.04	....	....	....	....	....	Trace.	.02	....	.03
CO_2	....	....	....	....	....	....	....	1.79	....	....
Total	99.42	100.07	99.11	100.67	100.01	....	99.99	100.18	99.98	100.46

a Chatard, analyst.
b Heddle, analyst.
c Analyst not named.
d Breidenbaugh, analyst.
e Melville, analyst.
f Steiger, analyst.
g Hillebrand, analyst.

[1] Am. Jour. Sci., Vol. XXVI, 1883, p. 230.
[2] Am. Jour. Sci., Vol. VI, 1873, p. 211.
[3] Bull. Geol. Soc. Am., Vol. II, p. 406.

GLOSSARY OF ROCK TERMS.

ALLOTRIOMORPHIC.—A term applied to those grains which do not attain their crystalline forms, as the interlocking quartzes of a quartzite (see Pl. XXXVIII) or the feldspars, etc., in a typical gabbro (see Pl. XLVII, No. 535). All mineral grains termed anhedrons (q. v.) must be allotriomorphic.

ANHEDRON.[1]—Mineral grains without crystal planes; to be used in apposition to crystal, which would therefore indicate idiomorphism, while the anhedrons would always be allotriomorphic.

AUTHIGENIC (also written "anthigenetic").—Applied to those minerals in a rock which have originated in it subsequent to its formation, as epidote and uralite in greenstones, or mica in mica-schists.

CATACLASTIC.—The structure produced in a rock by a crushing of the constituent minerals. The quartzes and feldspars are thus often broken up into a mosaic of smaller grains. The larger grains are sometimes faulted and bent, as is shown in the large feldspar in the photo-micrograph of No. 524 S. N. in Pl. XXXIX.

CLASTIC.—Composed of fragments and mineral particles derived from preexisting rocks, as a sandstone or a tuff. This structure is well shown in the photo-micrograph of No. 54, Pl. XXXVII.

COMPLEMENTARY ROCKS.[2]—A term applied by Brögger to the diverse differentiation products of a common magma. Thus, some camptonites and bostonites in Norway are thought to be the differentiation products from one magma and are called complementary.

CONTACT METAMORPHISM.—A term applied to the metamorphic action in a rock mass, along the border of the intrusive magma, which results from the intrusion of the igneous rock (exomorphic metamorphism). Some geologists also include, under contact metamorphism, the effect produced on the intrusive rock (endomorphic metamorphism). A fine illustration of contact metamorphism is the chiastolite-schist from Mariposa County formed from a clay-slate. See Pl. XXXV, B.

COUNTRY ROCK.—Used in the same way as the term is used by miners to designate the rock in which a mineral vein has formed. It may be made to designate the rock composing the walls of a dike. Thus, slate or schist is the country rock of most gold-quartz veins in California, and granite or quartz-mica-diorite is usually the country rock of most granulite (aplite) dikes. "Country rock" is thus often synonymous with "wall rock," but when the wall rock of a vein is a dike along the vein, the country rock would be of a different nature, and hence the two terms are not necessarily synonymous.

CRYPTOCRYSTALLINE.—An entirely crystalline rock in which the particles are too minute to be determined even with the microscope.

DIABASE STRUCTURE.—This term may be used to designate the *diabasisch-körnig* structure of Rosenbusch, characterized by the lath-like development (elongation following the edge *pg'* (001) (010)) of the feldspar and the later formation of the metasilicate. This will include the ophitic structure, but the metasilicate may occur in grains or wedge-shaped anhedrons between the feldspars, as shown in diabase 415 S. N., Pl. XLV, B, each grain of the metasilicate having a different crystallographic orientation. It is also evident that the diabase structure would be nearly identical with the latest definition of ophitic by Michel-Lévy,[3] in which "a bisilicate (pyroxene, amphibole) serves as a cement to the crystals of feldspar or to the other elements." (What other elements?)

DIKE.—As used by the author, this term supposes a preexisting fissure which has been filled with a molten magma, and is distinguished from the term "vein," inasmuch as the latter is filled by deposition from aqueous solutions. While all molten magmas

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[1] Dana and Pirsson, Bull. Geol. Soc. Am., vol. 7, p. 492.

[2] Brögger, Quart. Jour. Geol. Soc. London, Vol. L, p. 31.

[3] Structure et Classification des Roches Éruptives, 1889, p. 30.

may be regarded as solutions, those solutions that require an extremely high temperature for their existence can, in most cases at least, be separated from such solutions as are supposed to have formed mineral veins. We thus speak of basalt, andesite, and diabase dikes, and of quartz and calcite veins. The term "sandstone dike" is not objectionable even under the above definition, as it is plain that here is meant a fissure filled with sand.

GABBRO STRUCTURE.—When the different elements of a granular holocrystalline rock are in the form of irregular (allotriomorphic) grains with a nearly equal development in every direction, the rock has a typically granular structure called by Michel-Lévy the "structure grenue." This is very widespread in gabbros, and may be called the gabbro structure, and is well shown in the photomicrograph of 535 S. N., Pl. XLVII, an olivine-gabbro. The grains have a diverse orientation, and the structure differs from the granulitic in that there is no marked tendency to idiomorphism.

GNEISS.—This is used in the preceding paper as a structural term only for a thoroughly crystalline (often a recrystallized) rock in which the chief constituents are arranged in layers, producing a more or less distinct foliated structure, best seen in the hand specimen. Under the microscope gneisses are seen to have a thoroughly granular structure, with diverse orientation of the mineral grains, so that the foliated structure is chiefly due to the arrangement of the minerals in layers. As a rule, however, foliated and fibrous minerals, especially mica, are to a greater or less extent arranged with their longer axes parallel to the direction of schistosity, so that in nature gradations will be found between typical gneisses and typical schists.

GRANITIC STRUCTURE.—Following Michel-Lévy, this term is used to express the structure of most granites and quartz-diorites. It is partly synonymous with "hypidiomorphic" (Rosenbusch). The quartz, the last element to consolidate, serves as a cement to the other elements, some of which have nearly idiomorphic outlines. See the photomicrograph of quartz-diorite, No. 691 S. N., Pl. XLII. Judd[1] uses the term also for the hypidiomorphic structure of gabbros in which the augite and olivine are to some extent molded as the feldspar crystals. As suggested in other cases, the termination *oid* might be used, and the structure of such gabbros might be said to be granitoid. When the component minerals are of microscopic dimensions, the structure may be called microgranitic.

GRANULITIC STRUCTURE.—Michel-Lévy applies this term to the structure common in most granulites (aplites), in which the quartz and feldspar have an idiomorphic tendency, and both appear to have crystallized at the same time. In its typical development the grains are all about the same size and are independently oriented. When the grains are of microscopic dimensions, the structure may be called microgranulitic. A portion of the photomicrograph of No. 998 S. N., Pl. XXXIX, shows rather poorly the granulitic structure. Synonym: panidiomorphic (Rosenbusch), but in those granulites seen by the writer a typical panidiomorphic structure is never realized. The term is used by Judd[2] for a structure in certain gabbros, in which the pyroxene and olivine grains assume more or less rounded outlines. In polarized light these grains are seen not to be part of one large crystal, but to have different orientations. Bayley uses the term in the same way in describing gabbros.

HYALOPILITIC.—Applied by Rosenbusch to microlitic rocks which contain glass, and is especially characteristic of andesite. This structure is poorly shown in the photomicrograph of No. 72 S. N., in Pl. XLV, A.

INTRATELLURIC.[3]—A term applied by Rosenbusch to that period in the formation of a rock which immediately precedes eruption; also to the minerals which separate out during that period.

MACROSCOPIC.—As seen with the naked eye. Synonym: megascopic.

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[1] Quart. Jour. Geol. Soc. London, 1886, p. 67.
[2] Quart. Jour. Geol. Soc. London, 1886, p. 68.
[3] Rosenbusch, Massige Gesteine, 1885, p. 10.

MICROCRYSTALLINE.—When the constituents can be seen and identified, but only with the use of the microscope.

MICROLITIC STRUCTURE.—Following Michel-Lévy, this term is used to designate all those lavas in which the feldspar occurs in minute laths, as in trachytes, basalts, and andesites. This includes, therefore, the terms "pilotaxitic" and "hyalopilitic" of Rosenbusch.

MICROPEGMATITE.—A microscopic intergrowth of quartz and feldspar, each mineral having the same optical orientation throughout.

OPHITIC STRUCTURE (Michel-Lévy).—When the last element to crystallize is a metasilicate (usually pyroxene), and the mineral forms patches of greater or less size containing feldspars elongated following the edge *pg'* (001) (010); and, also, according to Lévy, flattened following *g'* (010), the plates of the metasilicate appear to be penetrated in all directions by the feldspar laths, presenting a characteristic structure, which was first set forth by Michel-Lévy[1] in describing some ophites from the Pyrenees, and has since been called the ophitic structure. This is most frequently found in diabases, but is not confined to them. In fact, one of the original ophites of Michel-Levy is an oligoclase-pyroxene rock, and would be called by the writer an ophitic pyroxene-diorite. The ophitic structure is illustrated in Pl. XLVI, A, a photomicrograph of a diabase from Calaveras County.

Michel-Lévy[2] defines ophitic thus: "A bisilicate (pyroxene, amphibole) serves as a cement to the crystals of feldspar or to the other elements." This evidently extends the term so that it is nearly or quite synonymous with Diabase structure. Synonyms: divergentstrahlig-körnig (Lossen); diabasisch-körnig (Rosenbusch) in part.

OPHITOID.—This word, analogous to pegmatoid, is suggested to be used to designate ophitic-like associations of minerals in which the inclosing substance is not a metasilicate. Thus, in quartz-diorite, No. 550 Calaveras, Pl. XLVI, B, the quartz and feldspar may be said to form an ophitoid structure.

PANIDIOMORPHIC.[3]—Nearly identical with the granulitic structure of Michel-Lévy. Rosenbusch states that it is characteristic of the aplites (granulites) and of some of his lamprophyric dike rocks, and is essentially different from the hypidiomorphic structure in that the minerals appear to have all formed at the same time. As applied to granulites an objection might be made to the term, which signifies all-idiomorphic, in that while there is an idiomorphic tendency to the minerals an actual condition of idiomorphism is seldom reached. It is best developed, so far as the writer's experience goes, in some of the diorites containing original hornblende needles. It is very poorly shown in Pl. XLIV, A, diorite 298, in which both the hornblende and the plagioclase are usually idiomorphic.

PEGMATOID STRUCTURE.—Used to designate an intergrowth of two minerals each of which has the same optical continuity throughout. The most common intergrowth is that of quartz and feldspar, forming pegmatite, but a similar intergrowth of other minerals takes place, as of tourmaline and quartz, as shown in Pl. XL, A. The term micropegmatoid may be used for the microscopic equivalent.

PILOTAXITIC STRUCTURE.—Applied by Rosenbusch to microlitic rocks, especially basalts, in which the groundmass is made up of minute feldspars in felted aggregation or arranged more or less nearly parallel and exhibiting a flow structure. Typical pilotaxitic rocks are said to be holocrystalline. The structure is included in the microlitic structure of Michel-Lévy.

PLEOCHROISM.—The property possessed by pellucid, doubly refractive minerals of transmitting rays of different colors or intensity in different directions. Uniaxial minerals are dichroic, since they possess two directions (parallel and normal to the chief axis) in which the greatest difference of color is shown. Biaxial minerals, on the other hand, are trichroic or polychroic, since they have three directions, corresponding to the three different axes of elasticity, along which rays of different intensity are transmitted.—TEALL.

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[1] Bull. Soc. Geol. de France, 1878, p. 157.

[2] Structure et Classification des Roches Éruptives, 1889, p. 30.

[3] Rosenbusch, Massige Gesteine, 1895, p. 461.

POIKILITIC STRUCTURE.[1]—Where patches of one mineral having the same optical orientation throughout include other minerals having a diverse orientation. Thus, in Pl. XLVII, A, the brown hornblende in gabbro, No. 985 S. N., contains numerous plagioclases lying at all angles. In this case, when the included mineral is feldspar, the structure differs from the ophitic structure only in the feldspars not being, as a rule, lath-shaped, but in short prisms, often with a very irregular exterior, as if broken up previous to the formation of the pyroxene. This poikilitic structure is not uncommon in gabbros.

In the large orthoclases of the porphyritic granite (No. 39 S. N.), described on page 479 of the Fourteenth Annual Report of the Geological Survey, Part II, there are inclusions of plagioclase, biotite, quartz, titanite, and iron oxide, with diverse orientation, and this may be regarded as another type of the poikilitic structure. Synonym: luster-mottling (Pumpelly). The term micropoikilitic is used when the structure can be seen only with the microscope.

PORPHYRY.—This term is used in the preceding paper in a purely structural sense, and signifies a holocrystalline igneous rock usually with a microcrystalline or cryptocrystalline groundmass in which are developed larger crystals (phenocrysts), often idiomorphic. So far as the writer is able to learn, the term porphyry has seldom been applied to coarse-grained rocks. The definitions given in Geikie and other standard manuals all refer to porphyries as fine granular rocks. The application of the term to coarse-grained granite with porphyritic feldspars (see paper in the Fourteenth Annual Report of the Geological Survey, Part II) appears to the writer to be inadvisable, although in a strictly logical use of the term, as signifying contrast of groundmass and phenocrysts, such a rock would be the true granite-porphyry, and the rock called in the present paper a granite-porphyry would be a microgranite(?)-porphyry.

PSEUDOSPHERULITES.—According to Teall, this term signifies spherulitic structures in which the rays are composed of two different substances which can be determined; these substances, usually, at least, are quartz and feldspar. The "étoilements des micropegmatites" of Michel-Lévy are of this character. When these rays or sectors are arranged about a fragment of older quartz, this extinguishes at the same time as the rays of the later quartz of the micropegmatite. (See also Spherulites with globular quartz.) The pseudospherulites also frequently form with feldspar prisms as a kernel. In this case the older feldspar of the kernel and the later feldspar of the micropegmatite do not necessarily extinguish together.

SALBAND.—The fine-grained border of a dike, due to the chilling action of the wall rock

SCHIST.—A structural term used to designate those rocks in which the mineral grains are chiefly elongated or flattened in one direction or lie in one plane, producing a cleavage which may be said never to be wholly wanting. The elongated or flattened grains need not be parallel, but may cross one another (as in some tremolite-schists) in all directions, forming a mesh work, but if such a schist is cut at right angles to the schistosity it will be noted that the fibers are chiefly in one plane. Schists are the result of dynamic action, and, according to Sorby, Van Hise, and others, the schistosity has been produced by a force acting in a direction normal to the cleavage plane. Many schists are derived from sedimentary rocks, in which the clastic character is still evident. Others are produced by the compression and shearing of massive igneous rocks.

SILICEOUS ARGILLITE.—This is proposed as a term to supplant "siliceous schist," or "kiesel-schiefer," inasmuch as the rocks so called are not schistose. The word "argillite" has, however, been used for schistose argillaceous rocks, but it is evident that the natural use of the term is simply to designate a clay rock, without specifying whether the rock is massive or schistose.

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[1] Williams, Jour. of Geology, Vol. I, p. 176.

SPHERULITE.—Following Cross,[1] a spherulite may be said to be a spherical body in which a radiate or concentric inner structure has been found to be a seldom-failing characteristic. Spherulitic structures are common in the acid lavas, in which the cryptocrystalline material, supposed to be usually quartz and feldspar, has a radially fibrous structure and shows a black cross between crossed nicols. Chlorite also often shows the same structure. The "quartz globulaire" of Michel-Lévy is a variety of the spherulitic structure in which a black cross is not ordinarily to be observed.

SPHERULITES WITH GLOBULAR QUARTZ.[2]—When the rays of pseudospherulites become so fine that they can not be resolved with the high powers of the microscope they pass into "spherulites à quartz-globulaire." Sometimes these constitute structures showing radiations in natural light, extinguishing in four positions at right angles between crossed nicols, or in two or more sectors. A good example of this is shown in the photomicrograph No. 247, Pl. XLI, B.

VEIN.—A fissure filled with mineral matter deposited from aqueous solutions, as a gold-quartz vein.

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[1] Bull. Philos. Soc. Washington, Vol. XI, p. 412.

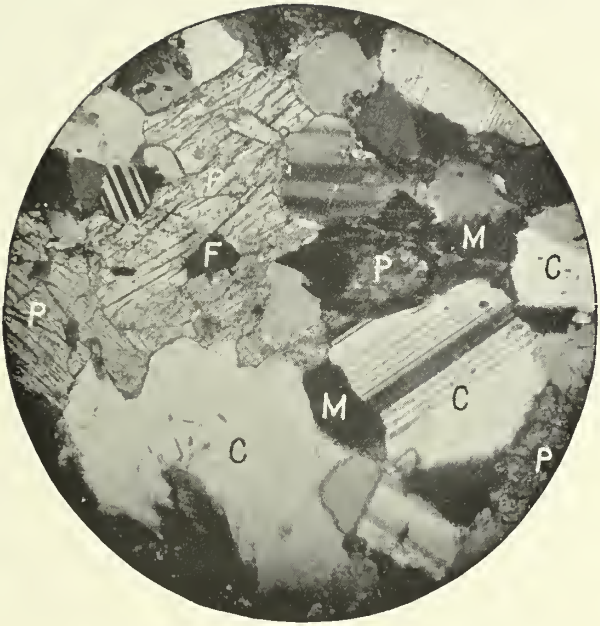
[2] Michel-Lévy, Structures of Rocks, p. 21.

PLATE XXXVII.

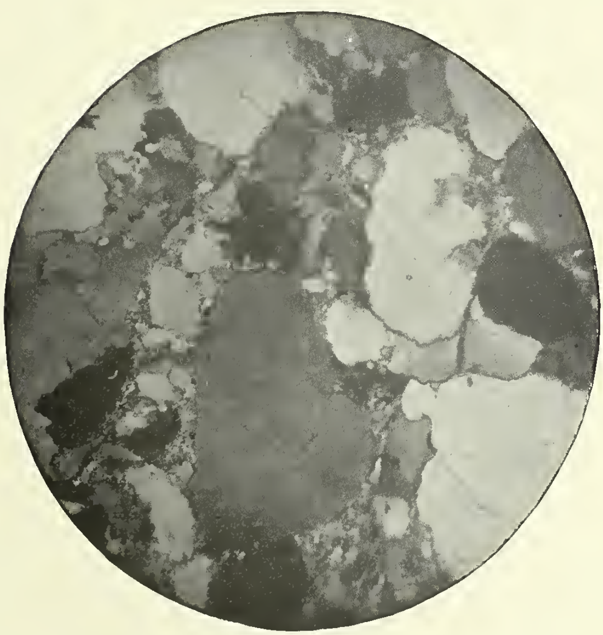
PLATE XXXVII.

A. Plagioclase-pyroxene-gneiss, No. 1456 S. N., showing the evenly granular structure. With the analyzer, × 50. C = plagioclase, andesine to labradorite; P = monoclinic pyroxene; M = black mica; F = iron oxide.

B. Quartzite from Pinoli Peak, No. 54 S. N., showing the clastic structure in part of section and the interlocking quartz grains in other portions. There has evidently been an addition of silica to the interlocking grains, so that their original outlines are but in part preserved. With the analyzer, × 53.



A



B

A. PHOTOMICROGRAPH OF PLAGIOCLASE-PYROXENE-GNEISS, NO. 1456 S. N.
B. QUARTZITE, NO. 54 S. N. SHOWING CLASTIC STRUCTURE IN PART OF SECTION.

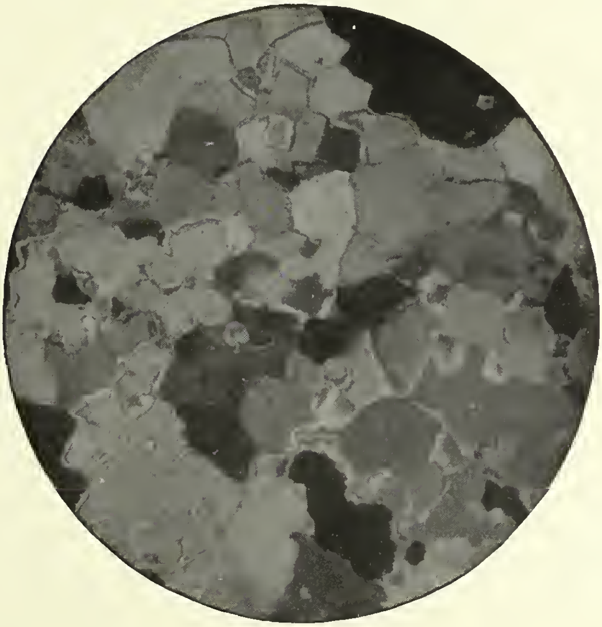
PLATE XXXVIII.

PLATE XXXVIII.

A. Quartzite, No. 183 Calaveras, showing the interlocking quartz grains. The shape of the original grains is not apparent, there being no visible line between the surface of the original quartz grains and the silica that has since been added. With the analyzer, × 20.

B. Quartz band in granulite, No. 998 S. N., showing the interlocking quartz grains, which in this case are certainly not clastic but of the nature of a vein deposit. With the analyzer, × 20.

A



B

A. QUARTZITE, NO. 183 CALAVERAS, SHOWING THE INTERLOCKING QUARTZ GRAINS.
B. QUARTZ BAND IN GRANULITE, NO. 998 S. N., SHOWING THE INTERLOCKING QUARTZ GRAINS.

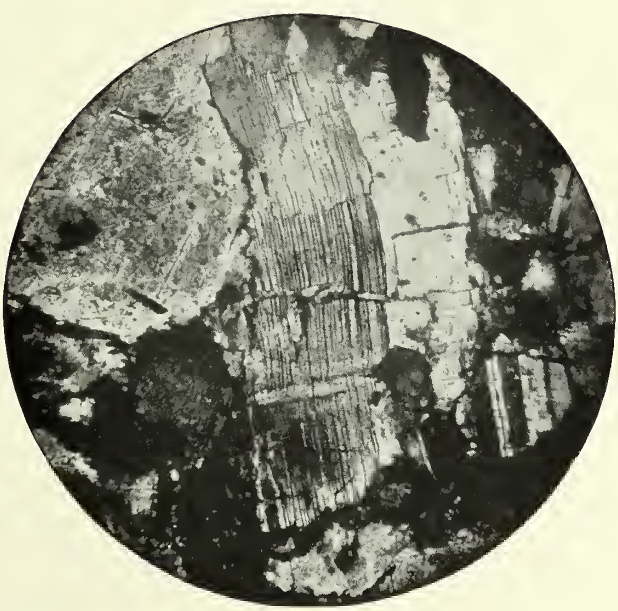
PLATE XXXIX.

PLATE XXXIX.

A. Granulite, No. 998, showing the granulitic structure in the upper part of the section, and micropegmatite in the lower part. With the analyzer, × 20.

B. Pre-Cretaceous tuff, No. 524 S. N., showing bent and fractured feldspar such as are found in cataclastic feldspathic rocks. This gives evidence of the rock having undergone crushing. With the analyzer, × 50.

A



B

A. GRANULITE, NO. 998, SHOWING GRANULITIC STRUCTURE AND MICROPEGMATITE.
B. BENT AND FRACTURED FELDSPAR IN PRE-CRETACEOUS TUFF.

PLATE XL.

PLATE XL.

A. Pegmatoid intergrowth of tourmaline and quartz, No. 928 S. N. Without the analyzer, × 20. This rock formed part of a pegmatite dike in quartz-pyroxene-diorite southeast of Sonora.

B. Granite, No. 39 S. N., showing the large idiomorphic titanites with prongs on the sides of the largest prism. Without the analyzer, × 55.

A = hornblende; M = black mica; F = iron oxide; D = apatite.

A

B

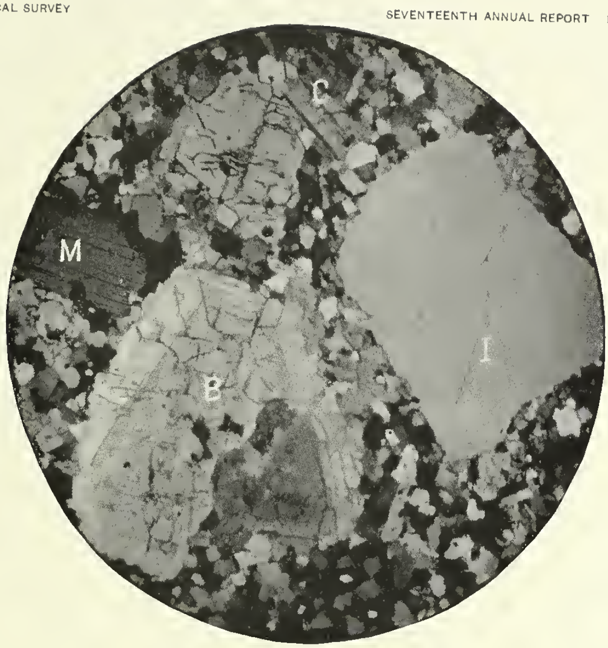
A. PEGMATOID INTERGROWTH OF TOURMALINE AND QUARTZ, NO. 928 S. N.
B. GRANITE, NO. 39 S. N., WITH IDIOMORPHIC TITANITE AND HORNBLENDE.

PLATE XLI.

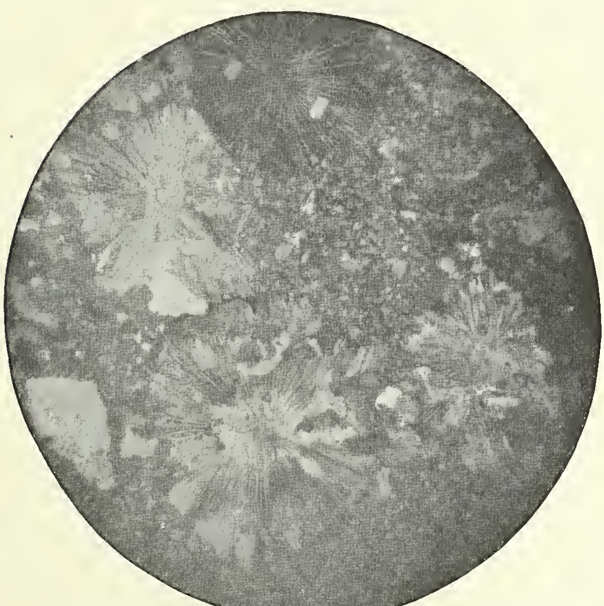
PLATE XLI.

A. Granite-porphyry, No. 40 S. N., showing a typical microcrystalline groundmass. With the analyzer, × 20. A = quartz; B = orthoclase; C = plagioclase; M = biotite.

B. Spherulitic quartz-porphyry, No. 247 Amador, illustrating the "quartz-globulaire" structure of Michel-Lévy. With the analyzer, × 45. All parts of any one spherulite extinguish simultaneously or nearly so, or any one spherulite extinguishes in sectors. In the photomicrograph all of the upper spherulite is extinguished except a few faint radii. A black cross is ordinarily not to be observed.



A



B

A. GRANITE-PORPHYRY, NO. 40 S. N., SHOWING A TYPICAL MICROCRYSTALLINE GROUNDMASS.

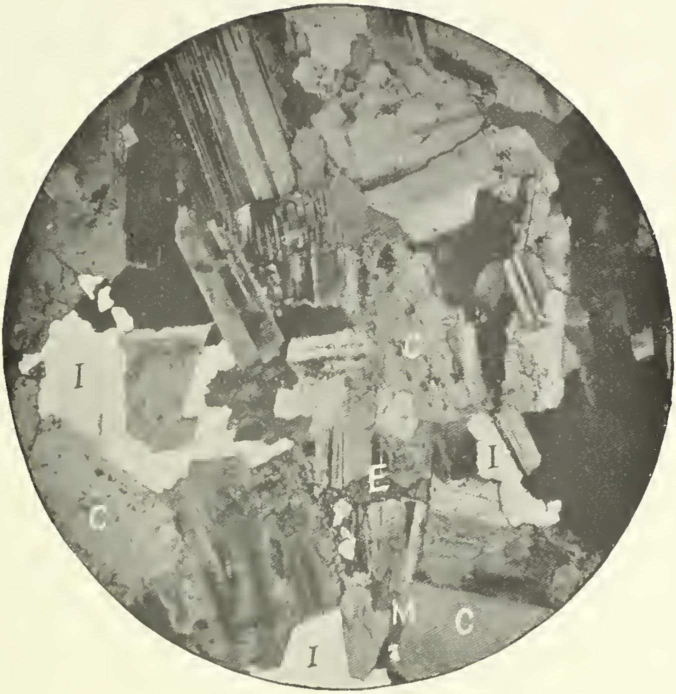
B. SPHERULITIC QUARTZ-PORPHYRY, NO. 247 AMADOR.

PLATE XLII.

PLATE XLII.

A. Quartz-mica-diorite, No. 691 S. N., showing the granitic or hypidiomorphic structure. With the analyzer, × 20. I = quartz, which is the last element to crystallize and fills the interstices between other minerals; C = plagioclase (andesine and labradorite); M = biotite; E = epidote.

B. Pyroxene-diorite, No. 165 S. N., showing the idiomorphic augite inclosed in feldspar. Without the analyzer, × 20. P = augite, some of which shows the diallage cleavage; H = hypersthene; M = biotite; F = iron oxide.



A

B

A. QUARTZ-MICA-DIORITE, NO 691 S. N., SHOWING THE GRANITIC OR HYPIDIOMORPHIC STRUCTURE.

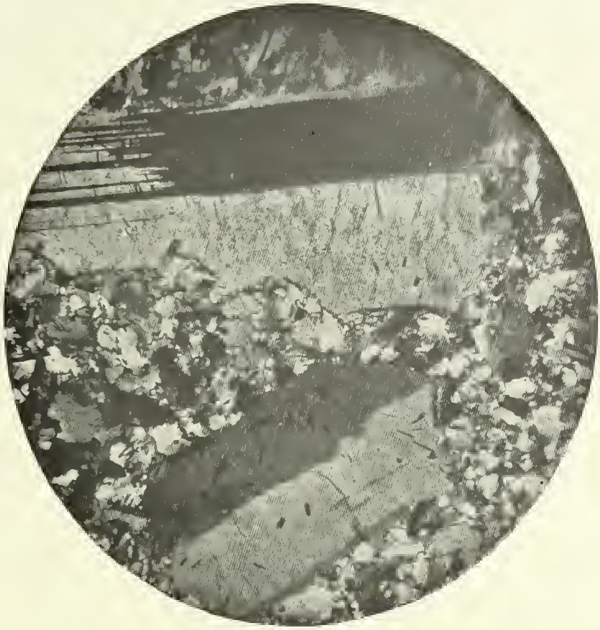
B. PYROXENE-DIORITE, NO. 165 S N., SHOWING THE IDIOMORPHIC AUGITE INCLOSED IN FELDSPAR.

PLATE XLIII.

PLATE XLIII.

A. Soda-syenite-porphyry, No. 46 Tuolumne, showing the microcrystalline groundmass of albite grains in which are embedded phenocrysts of plagioclase. With the analyzer, × 50.

B. A view of another portion of the same section as the previous, showing radiating brushes of delicate blue hornblende needles. Without the analyzer, × 50.



A

B

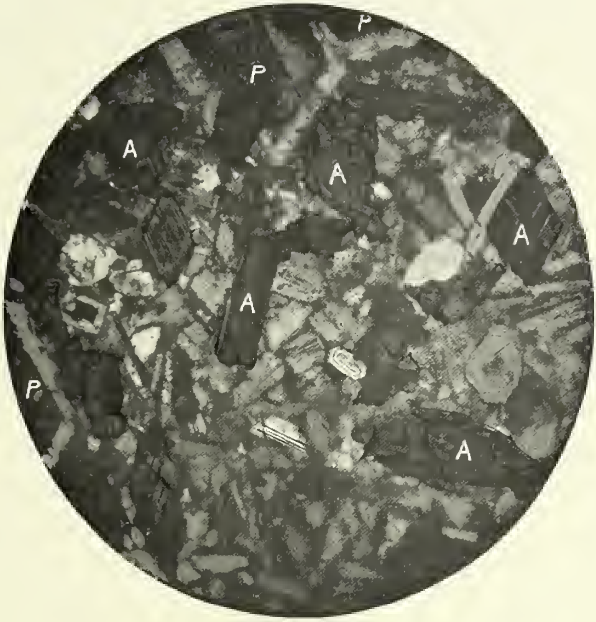
A. SODA-SYENITE-PORPHYRY, NO. 46, TUOLUMNE COUNTY.
B. RADIATING TUFTS OF HORNBLENDE IN SODA-SYENITE-PORPHYRY, NO 46.

PLATE XLIV.

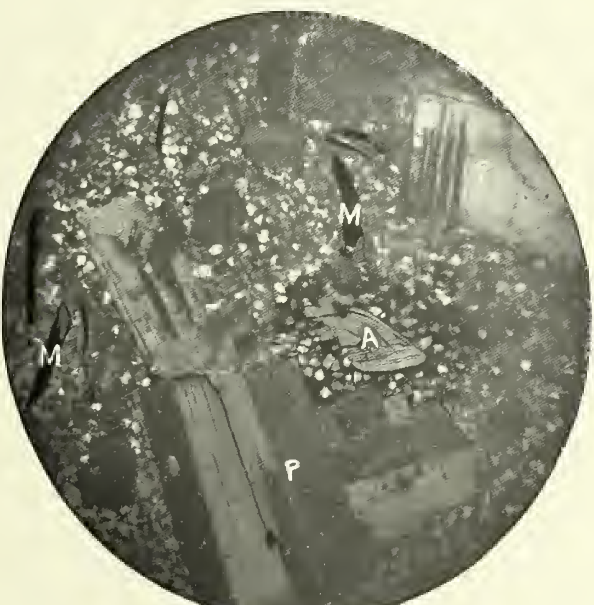
PLATE XLIV.

A. Diorite-porphyry, No. 298 S. N., showing the idiomorphic tendency of the plagioclase and hornblende. With the analyzer, × 45. P = plagioclase phenocrysts with decomposed interior and rim of fresh feldspar; A = brown hornblende. The smaller plagioclases of the groundmass likewise have idiomorphic tendency, so that the rock has a nearly panidiomorphic structure.

B. Quartz-diorite-porphyry, No. 298 S. N., view of part of the same section as the previous, the section being made from a chip taken at the contact of the two dikes. The microcrystalline nature of the quartz-feldspar groundmass is shown, and in this groundmass are embedded plagioclase phenocrysts. With the analyzer, × 45.



A



B

A. DIORITE PORPHYRY, NO. 298 S. N.
B. QUARTZ-DIORITE-PORPHYRY, NO. 298 S. N.

PLATE XLV.

PLATE XLV.

A. Hornblende-pyroxene-andesite, No. 72 S. N., showing the porphyritic plagioclase with glass inclusions. P = augite grains. The microlitic glassy groundmass illustrating the hyalopilitic structure of Rosenbusch is not brought out. With the analyzer, × 55.

B. Diabase, No. 415 S. N., showing the wedges of hornblende between the lath-shaped feldspars, and illustrating imperfectly the diabase-granular structure, the chief feature of which is the lath-like development of the feldspars with later metasilicates. With the analyzer, × 50.

A

B

A. HORNBLENDE-PYROXENE-ANDESITE, NO. 72 S. N., SHOWING THE PORPHYRITIC PLAGIOCLASE WITH GLASS INCLUSIONS.

B. DIABASE, NO. 415 S. N., SHOWING THE WEDGES OF HORNBLENDE BETWEEN THE LATH-LIKE FELDSPARS.

PLATE XLVI.

PLATE XLVI.

A. Diabase, No. 175 Calaveras, showing the lath-shaped feldspars penetrating in all directions the later plates of augite. This constitutes the typical ophitie strueture of ophites as first figured by Miehel-Lévy. With the analyzer, × 40.

B. Quartz-augite(?)-diorite, No. 550 Calaveras, showing the lath-shaped feldspars penetrating the later green hornblende and quartz. The hornblende presumably represents original pyroxene, but the quartz is primary. I = quartz; A = hornblende. With the analyzer, × 20.

A

B

A. DIABASE, NO. 175 CALAVERAS, SHOWING THE OPHITIC STRUCTURE.
B. QUARTZ-DIORITE, NO. 550, CALAVERAS, SHOWING THE OPHITOID STRUCTURE OF THE PLAGIOCLASE IN THE QUARTZ.

PLATE XLVII.

PLATE XLVII.

A. Poikilitic gabbro, No. 985 S. N., showing the broken and corroded anorthites inclosed in later brown hornblende. The feldspars lie at all angles in the hornblende plate, which has the same optical orientation throughout. This is an illustration of the typical poikilitic structure as characterized by Prof. G. H. Williams. With the analyzer, × 20.

B. Gabbro, No. 535 S. N., showing the gabbro or typical granular structure in which both the main constituents, pyroxene and plagioclase, appear to have crystallized at about the same time, the anhedrons of each mutually interfering, so that none of the grains attained their proper crystalline forms. With the analyzer, × 40. C = plagioclase; A = hornblende; P = augite; H = hypersthene; F = iron oxide.

A

B

A. POIKILITIC GABBRO, NO. 985 S. N.
B. GABBRO, NO 535 S N, SHOWING THE GABBRO OR TYPICAL GRANULAR STRUCTURE.

REPORT ON COAL AND LIGNITE OF ALASKA.

BY

WILLIAM HEALEY DALL.

CONTENTS.

ILLUSTRATIONS.

REPORT ON COAL AND LIGNITE OF ALASKA.

By W. H. Dall.

INTRODUCTION.

The following report is intended to include a full account of what is known with regard to the deposits of fossil fuel in Alaska embraced under the head of coal or lignite. An account of the various localities visited by our party in 1895 is supplemented by data obtained by the writer on previous visits to the Territory, especially to such places as were not included in the list of those visited on the present occasion.

To this is added a general discussion of the coals or lignites from an economic standpoint, with analyses of the Alaskan and similar coals for comparison, tests of their practical utility, and general conclusions as to their value.

A summary of our knowledge of the Cenozoic geology of Alaska is next given, including a discussion of the geologic age of the coal-bearing beds, and an enumeration of the localities where Cenozoic rocks have been observed, both by the author and others during explorations in Alaska and by the Survey, with a list of the fossils obtained from them.

Brief summaries of what is known in regard to the fossiliferous horizons of Alaska follow, including a full description of the localities visited by our party in 1895.

To these are added three appendices on the fossils collected, including a report on the fossil plants by Dr. F. H. Knowlton, wherein are enumerated the species known to date as having been collected in Alaska; a report on the Paleozoic invertebrates by Mr. Charles Schuchert, of the U. S. National Museum; and a preliminary report on the Mesozoic fossils by Prof. Alpheus Hyatt. A discussion of the Cenozoic fossils by the writer is included in the chapter on the Cenozoic geology of Alaska.

Our work in the Alexander Archipelago was carried on while guests on board the U. S. S. *Pinta*, and to Lieut. Com. A. R. Couden, U. S. N., commanding, and his officers, we are under obligations for every aid in their power.

LOCALITIES OF THE COAL-BEARING KENAI FORMATION.

ALEXANDER ARCHIPELAGO.

ST. JOHN BAPTIST BAY.

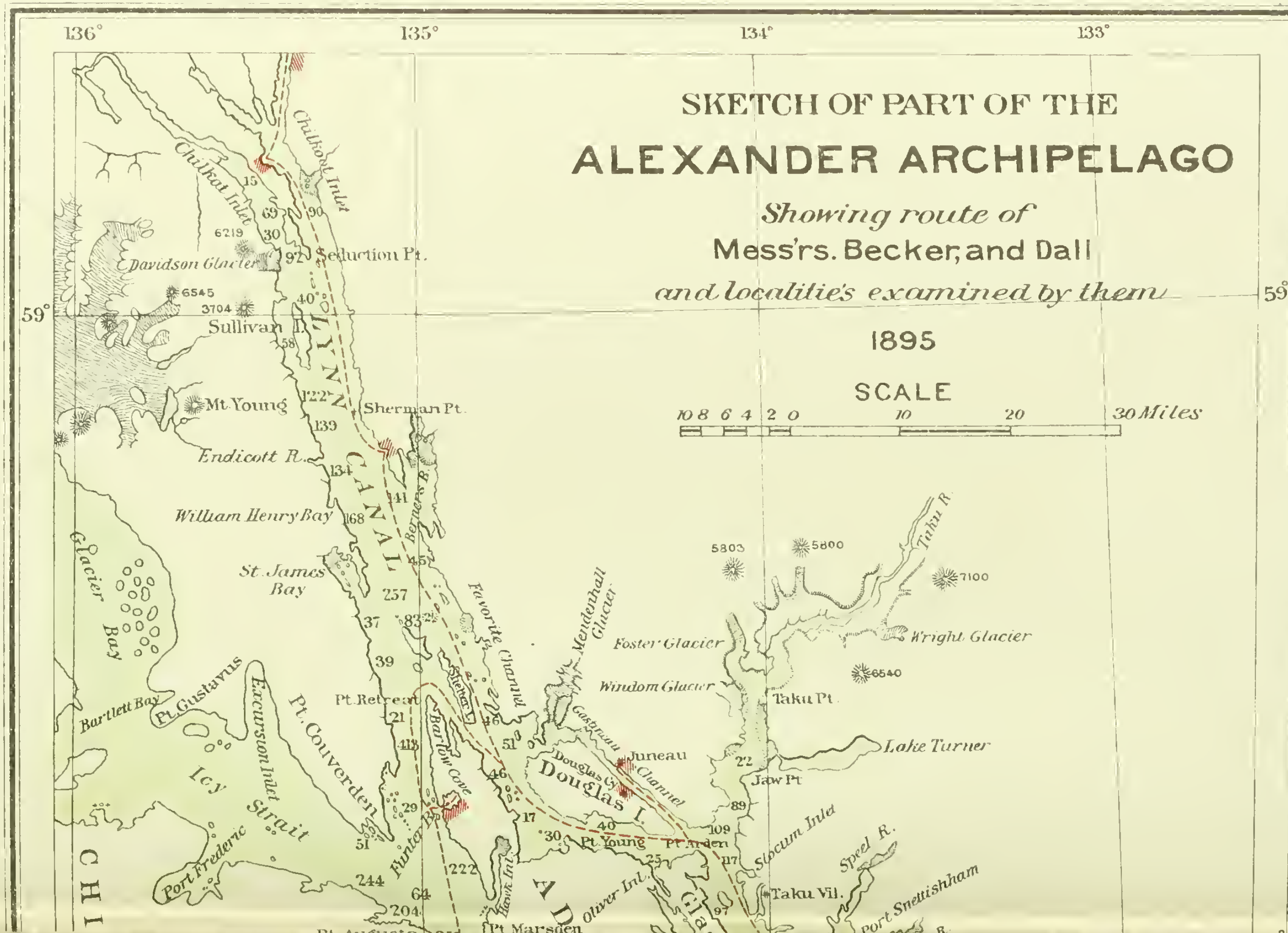
About 16 miles[1] in a northwesterly direction from Sitka, and just north of Point Zeal, a small open bay extends to the eastward, called by the Russians Joanna Predtechi or St. John Baptist Bay. On the shores of this bay, according to reports received as correct among the Russians, fragments of coal have been found. It was supposed that in the vicinity beds of coal might occur from which these float fragments came. By the aid of the *Pinta's* steam launch a visit to this bay and an examination of the rocks were made. The rocks about the shores and the material brought down by several good-sized streams which fall into the bay were carefully scrutinized. Only granitic and dioritic rocks were found in place, with occasional bands of graphitic slates.

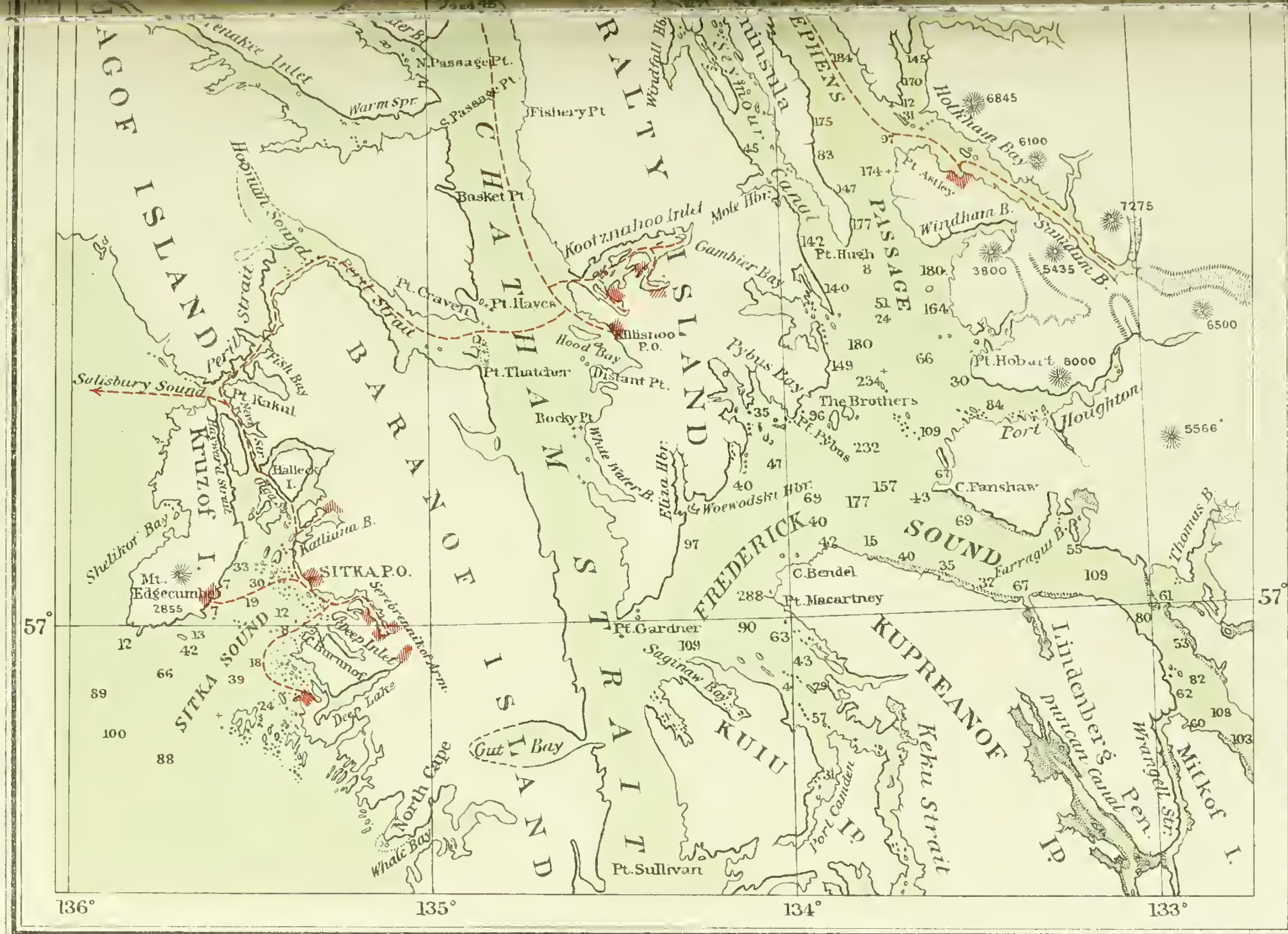
The only authentic reference to coal in this vicinity is found in Davidson's Alaska Coast Pilot of 1869, p. 35, where he says:

> The most important discovery was made by the Coast Survey in October, 1867, in the valley at the head of St. Johns Bay, opening upon Neva Strait about 17½ miles north of Sitka. Pieces of coal largely intermixed with rock, to which their preservation was due, were found for 4 or 5 miles along the bed of the small but rapid stream. After a second partial exploration and obtaining large specimens it was believed the coal was anthracite, but a subsequent analysis in San Francisco proved it to be bituminous. From all the geological evidence, the geologist reported that the bed or beds from which it was broken will, if discovered, afford coal of vastly superior quality to any heretofore known to exist in the Territory. * * * Recent information has been received that this coal vein which has been discovered is of great thickness, is anthracite, has been burned on a United States steamer and reported upon favorably. The general course of the stream upon which specimens were found is east and west; its rise for the first 4 or 5 miles is not very rapid. Along its banks are small areas of flat alluvial land, particularly near its mouth. The channel often separates into two or three, inclosing small islands on the level bottom land. The rocks in situ are rarely exposed, but at two points on the stream fine black shales and soft friable sandstones, without fossils, however, were seen trending approximately northeast and southwest and inclined at a high angle. Pieces of coal much intermixed with foreign substances, principally limestone, of greater or less size, were found along the course of the stream for a distance of 4 miles. Highly crystalline limestone, white, streaked with gray, was found in the detritus. The dense growth of timber, thick masses of fallen and decaying trees, covered with deep moss, thickets of the thorny shrub *Panax horridum*, and the general mountainous character of this locality will render its future exploration extremely difficult.

The notes cited by Professor Davidson, except the sentence referring to later information, are by Mr. Theodore A. Blake, geologist to the Coast Survey party which visited Alaska on the revenue cutter *Lincoln* in 1868. There would seem to be no doubt that Mr. Blake found coal, as stated; but his account of the topography leads to the impression that

[1] The mile used in this report is the nautical mile of 6,080 feet.


SKETCH OF PART OF THE
ALEXANDER ARCHIPELAGO
Showing route of
Mess'rs. Becker, and Dall
and localities examined by them
1895
SCALE
10 8 6 4 2 0 10 20 30 Miles
136°
135°
134°
133°
59°
Chilkoot Inlet
Chilkat Inlet
Seduction Pt.
Davidson Glacier
Sullivan I.
LYNN CANAL
Mt. Young
Sherman Pt.
Endicott R.
William Henry Bay
Berners B.
St. James Bay
Glacier Bay
Favorite Channel
Mendenhall Glacier
Foster Glacier
Windom Glacier
Gastineau Channel
Juneau
Douglas I.
Douglas Cy.
Taku R.
Wright Glacier
Taku Pt.
Lake Turner
Jaw Pt.
Slocum Inlet
Speel R.
Taku Vil.
Port Snettishham
Pt. Retreat
Barlow Cove
Shelter I.
Pt. Couverden
Excursion Inlet
Pt. Gustavus
Bartlett Bay
Icy Strait
Port Frederic
Funter B.
Hawk Inl.
Oliver Inl.
Pt. Young
Pt. Arden
Pt. Marsden
CHI



CHATHAM STRAIT
BARANOF ISLAND
FREDERICK SOUND
KUPREANOF ID.
KUIU ID.
PASSAGE
ISLAND
SITKA SOUND
Kruzof I.
Mitkof I.
Lindenberg Pen.
Duncan Canal
Wrangell Str.
Keku Strait
Port Camden
Saginaw Bay
Pt. Gardner
Pt. Sullivan
Pt. Macartney
C. Bendel
C. Fanshaw
Port Houghton
Pt. Hobart
The Brothers
Pt. Pybus
Pybus Bay
Eliza Hbr.
Woewodski Hbr.
White Water B.
Rocky Pt.
Distant Pt.
Hood Bay
Killisnoo P.O.
Kootznahoo Inlet
Gambier Bay
Mole Hbr.
Pt. Hugh
Windham B.
Sumdum B.
Hotham Bay
Pt. Astley
Pt. Thatcher
Pt. Hayes
Pt. Craven
Peril Strait
Hoonah Sound
Fish Bay
Pt. Kakul
Salisbury Sound
Hayward Strait
Neva Str.
Olga Str.
Halleck I.
Katlian B.
SITKA P.O.
Serebrennikof Arm.
Deep Inlet
C. Burunof
Deep Lake
Mt. Edgecumbe 2855
Shelikof Bay
North Cape
Whale Bay
Gut Bay
Basket Pt.
Fishery Pt.
N. Passage Pt.
S. Passage Pt.
Warm Spr.
Tenakee Inlet
Farragut B.
Thomas B.
57°
136°
135°
134°
133°
JULIUS BIEN & CO. N.Y.

the locality was wrongly identified, and that it was one of the other numerous bays in the vicinity and not the true St. John Baptist Bay explored by us. In the latter there is certainly no room between the mountains and the sea for a stream 4 or 5 miles long, and we found no traces of limestone, sandstone, or coal in the vicinity. The statement that a vein of anthracite had been discovered may refer to some other locality where the Alaskan coal, which much resembles anthracite, has been found, but is certainly erroneous if applied to this locality. If such a seam had been found near Sitka, the high price of coal there would have made it a matter of great importance to the inhabitants, and its existence would have been generally known; whereas no one among the many of whom inquiries were made at Sitka had ever heard of any such discovery. The report of Mr. Blake[1] referring to the drifted fragments of coal was known to many, but nothing more, except vague rumors handed down from the Russian inhabitants, who may have been misled by the fact that portions of the black slates contain thin sheets of graphite, which might cause them to be mistaken for anthracite by inexperienced persons.

Our conclusion, therefore, is that there is no satisfactory evidence at present of the presence of coal or the rocks of the age of the coal in this particular locality.

POINT GARDNER.

The southern extreme of the Admiralty group of islands, separating Chatham Strait and Frederick Sound, was named Point Gardner by Vancouver. Near it is a small anchorage, partly sheltered by some islets, and named Surprise Harbor. In September, 1868, Capt. J. W. White, of the U. S. revenue steamer *Wayanda*, discovered fragments of coal in a small stream falling into the head of the harbor. Two miles from the shore, at an elevation of 500 feet above the sea, a small vein of coal in soft clay, without fossils, cropped out of the right bank. About 100 feet farther up the stream there was a larger vein in a similar formation. Both were of poor quality and only a few inches in thickness. They dipped 60° to the southeast, with a strike from southwest to northeast.[2]

Some years later an attempt was made to develop coal in this vicinity by Capt. James Carroll and others. The seam selected is stated to have been found 800 feet above the sea level and about 2 miles from the beach. A tunnel 210 feet long tapped the seam at a distance of 40 feet from the surface; and 25 feet lower another tunnel, intended to strike the same seam at a lower level, was run to a depth of 120 feet.[3] The seams were covered by sandstone, with a greasy sort

[1] Report on the Geology of Alaska, by Theodore A. Blake, House Ex. Doc. No. 177, Fortieth Congress, second session, February, 1868, pp. 314–325.

[2] Cruise in Alaska, Senate Ex. Doc. No. 8, Fortieth Congress, third session, January, 1869, p. 8.

[3] Eleventh Census, Report on Alaska, 1893, p. 236.

of shale below, and were more or less interleaved with carbonaceous shale, the whole series being about 7 feet thick.

The rocks proved to be much broken and faulted, and the coal to be of inferior quality and in small quantity, so that, after the expenditure of several thousand dollars in prospecting, the mine was abandoned, as having under present conditions no commercial value.

PORT CAMDEN.

This is a large bay penetrating Kuiu Island from the northeast, opening upon Keku Strait near Frederick Sound. In May, 1868, coal was discovered here by Capt. J. W. White, of the U. S. revenue steamer *Wayanda*. The seam crops out on the east side of the bay, about 7 miles south of the entrance, in about latitude 56° 42′, according to the charts. Captain White states[1] that the coal is 20 feet above low-water mark, and occurs in several veins about 6 inches thick, with intervening strata of hard rock. The coal seams are at varying distances of 20 to 50 feet from each other, increasing in thickness inward, with a dip of 35° or 40° to the southward and a strike nearly east and west. Immediately below the upper vein is a layer of clay rock, with abundant fossil remains; above this vein is a layer of gray siliceous conglomerate. As far as could be observed, the strata inclosing the lower seams were similar. On account of the steep angle of the dip the seams could not be traced far. The bay affords good anchorage, with a range of tide of about 30 feet; the surrounding country is thickly wooded. It is not unlikely that this is one of the localities alluded to in Furuhjelm's notes (published by Oswald Heer)[2] as located on Keku Strait, but of which Heer has not stated the exact position.

WHALE BAY, BARANOFF ISLAND.

This bay is situated about 23 miles southeast from Sitka, and has not been accurately surveyed. On the shores of the eastern arm of this bay, according to Russian reports, sandstones containing plant remains and small seams of lignite have been observed. No recent explorations of this locality have been made, and our time was too short to allow us to attempt to visit it. It is probable that if coal seams of any size occur at Whale Bay they would have been reported by prospectors, some of whom are known to have visited the place in search of mineral deposits.

KUIU ISLAND.

The eastern shore of Chatham Strait, between 56° and 57° north latitude, is formed by the extremely broken and irregular island of Kuiu

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[1] Cruise in Alaska, Senate Ex. Doc. No. 8, Fortieth Congress, third session, 1869, p. 2; see also Davidson, Coast Pilot of Alaska, 1869, p. 35.

[2] Flora fossilis Alaskana; Kongl. svensk. Vet.-Akad. Handl. Bd. 8, No. 4, Stockholm, 1869, pp. 7–8.

(pronounced Koo-yoo), sometimes called Kake Island, from the Kake tribe of Indians which inhabit its shores.

On the west coast of Kuiu, in about latitude 56° 25′, rocks of the Kenai formation occur, of which the following description is condensed from notes by Furuhjelm.

The outcrop is between tide marks, and consists of a sandstone with remains of a hazel (*Corylus McQuarrii*), dipping inland about 25° or 30°, which contains thin layers of blackish-gray shale in pairs, each pair enclosing a layer of brown coal or lignite varying from 6 inches to 7½ feet in thickness. The shale contains plants, especially conifers. Above these and rising above high-water mark is a coarse-grained sandstone overlain by a coarse conglomerate covered by about 15 feet of humus and turf. The whole section includes a belt somewhat more than 200 feet wide, on the eroded surface of which are strewn numerous erratic blocks of granite. The section has a good deal of resemblance to that exposed at Coal Bay, Unga Island, at least in the succession of the plant beds, coal, and conglomerate.

The shales from this locality afforded *Sequoia langsdorfii*, and species of Glyptostrobus, Pteris, and Castanea. The coal contained 16 per cent of water, about 3 per cent of ash, about 35 per cent of volatile and 45 per cent of fixed carbonaceous matter, according to Genth.[1] The occurrence of lignite near Sitka is also noted by Erman,[2] who makes no precise identification of locality, but probably refers to these beds.

Of the plants found in these beds a number are common to Ninilchik, Port Graham, and other beds of the Kenai formation in Alaska. On Keku (or Kake) Strait, which separates Kuiu from Admiralty Island, several outcrops of beds of the same age and general character have been noted by Furuhjelm and others, on both the Admiralty and the Kuiu Island shores, and a few fossil plants have been collected and examined by Dr. Newberry,[3] of which he reports several species to be identical with those of Kenai. No workable seams of coal have yet been reported in connection with these localities.

Plant beds, or traces of lignite, have also been reported on the north shore of the Lindenberg Peninsula, Kupreanoff Island; on the mainland opposite the last-mentioned place; at the southeastern extreme of Chichagoff Island, on Chatham Strait; near Hood Bay, on the opposite side of the strait;[4] on the shores of Prince of Wales Island, near Kasaan Bay; and in the northern part of Seymour Canal, Admiralty Island. No workable coal at any of these localities

[1]K. k. geol. Reichsanstalt. Wien, 1868, p. 397; Heer, op. cit., p. 4.

[2]Reise um die Erde, vol. 3, p. 213.

[3]Brief descriptions of fossil plants, chiefly Tertiary, from western North America, by Dr. J. S. Newberry: Proc. U. S. Nat. Mus., Vol. V, pp. 502–514; February, 1883. The author describes five species from Cook's Inlet, two from Admiralty Island, Seymour Canal, and one from Kake Strait, near Kootznahoo, Alaska.

[4]This coal is said to have been explored and condemned as worthless by the Russians. Cf. Davidson, Coast Pilot of Alaska, 1869, p. 35.

is reported, and the time available was too brief to permit of spending it in exploration in the absence of more definite information.

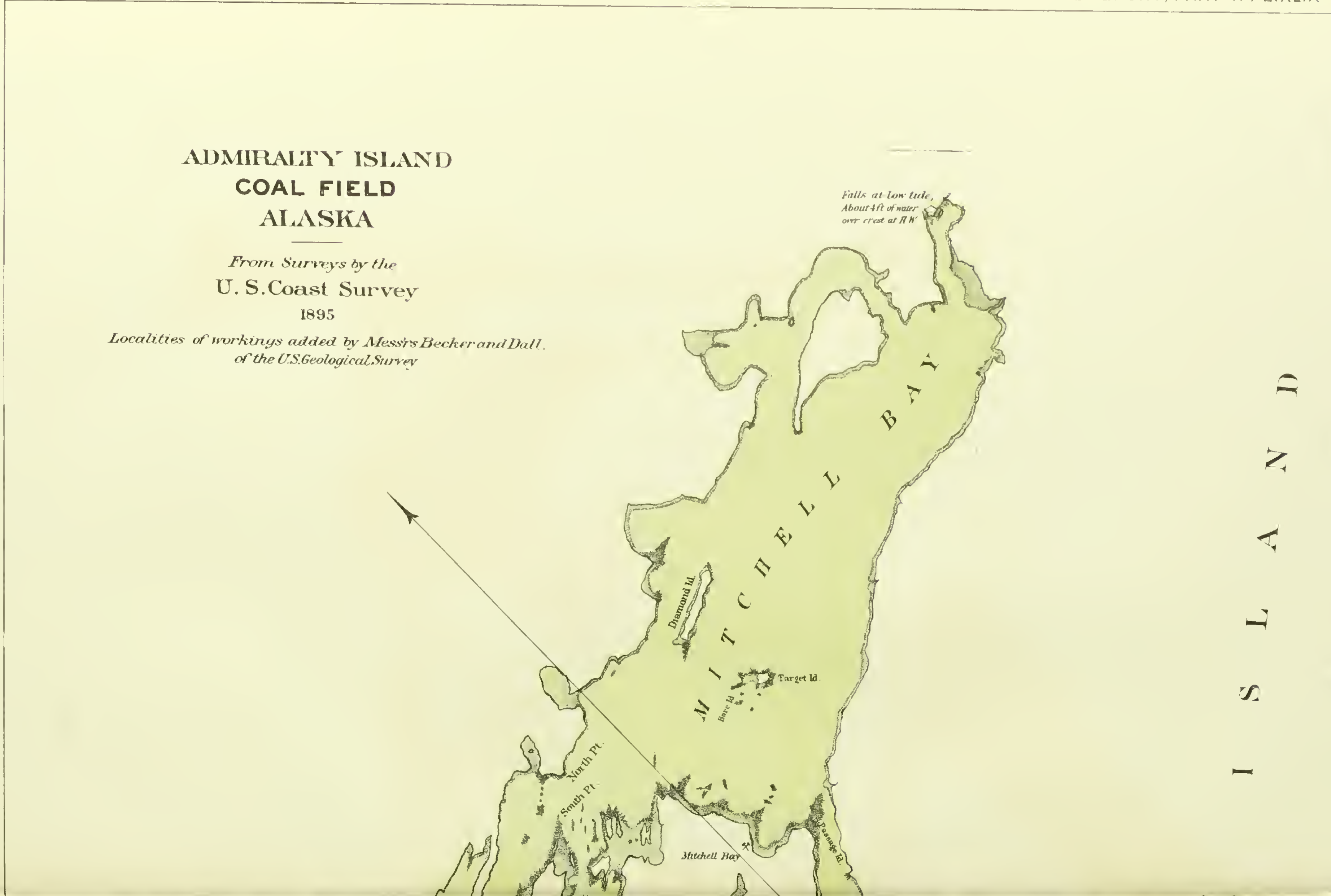
KOOTZNAHOO INLET, ADMIRALTY ISLAND.

The only locality in the Alexander Archipelago where the information on record warranted hopes of finding commercially valuable coal was in the central part of Admiralty Island, about the singular and complex waterways which, collectively, have been known as Kootznahoo Inlet. This name, of Indian origin, means "home of the bears," or place frequented by bears, the totemic symbol of the Kootznahoo natives being a bear. On the west shore of the Admiralty group, north of Hood Bay, is the harbor and settlement now known as Killisnoo, the site of an important herring fishery and manufactory of fish guano. There is also an Indian village on the north side of the entrance to the harbor, which, according to the census of 1890, had 192 inhabitants. This is Kootznahoo, and the village is situated so that a few minutes' walk from the landing south of it carries one across a narrow neck to the Kootznahoo Inlet. The entrance of the inlet is on Chatham Strait, due east from Point Hayes and north of Danger Point. It is very narrow and rocky, and, since the ramifications of the inlet cover many square miles and the tide must rise or fall entirely through this narrow opening, the current through the entrance is extremely strong. It is in fact only practicable to enter at slack water even with steam power, and the tide rips caused by the ebb off Danger Point are very heavy. Except for this strong tide and the narrowness of the passages the inlet offers good facilities for navigation. There is abundance of water, and few submerged dangers, clear to the head of the principal arms. If the shores of the inlet should prove to contain commercially valuable coal, there is nothing in the difficulties of navigation for steam vessels to prevent its being made available. By accommodating their movements to the tides skillful navigators would encounter nothing alarming.

The accompanying map (Pl. XLIX), for which we are indebted to the Coast and Geodetic Survey, will enable the reader to form a better idea of this maze of waters than any amount of description.

The land about the inlet is rather low and moderately level, mostly wooded with spruce and hemlock. The rocks are chiefly shales and sandstones, which, toward Chatham Strait, are crumpled and faulted, but appear less so in proportion as one passes northeasterly from the entrance, in the direction of a cluster of low mountains which may be seen in the distance. The strata about the northeastern extreme of the inlet in the vicinity of McCluskey's claim were obviously less disturbed and more nearly horizontal than in any other part of the inlet visited by us.

It was stated by residents at Killisnoo that light earth tremors, or


ADMIRALTY ISLAND
COAL FIELD
ALASKA
From Surveys by the
U. S. Coast Survey
1895
Localities of workings added by Messrs Becker and Dall.
of the U.S.Geological Survey
MITCHELL BAY
ISLAND
Falls at low tide,
About 4 ft of water
over crest at H.W.
Diamond Id.
Target Id.
Bare Id.
North Pt.
South Pt.
Mitchell Bay
Passage Id.


ADMIRALTY
KANALKOO BAY
Creek
134° 25' approx.
Meade Mitchell
Lighter Creek
Brightman (118)
Sepphagen shaft (115)
FAVORITE BAY
Fishing Station
Sullivan Pt.
Long Id.
Channel Pt.
Rose Rk.
Village Rk.
Stillwater Anchorage
Pt. Pillsbury
Pt. Bridge
Turn Pt.
Danger Pt.
SCALE
Miles
CHATHAM STRAIT
JULIUS BIEN & CO N.Y.

even mild shocks, were not uncommon there. This fact might have a bearing on the prosecution of mining in the district thus affected.

Nearly all the lowlands surrounding the ramifications of Kootznahoo Inlet are underlain by the sandstones and shales of the Kenai formation, and coal seams are of frequent occurrence. Our observations were limited to those upon which some work of exploration or prospecting had been done, nearly all of which are near the shores of the inlet. The different locations are known by the names of the persons who have endeavored to explore them, and will be so referred to in this report. We were indebted to Captain Moore, of the Coast Survey steamer *Patterson*, whose staff was engaged in surveying the inlet, for transportation by steam launch to the various outcrops, and to Messrs. Brightman and McCluskey, of Killisnoo, for services in guiding us to various places where exploration of the coal seams had been attempted.

The discovery of this coal field was made in 1868, when a native brought to Sitka some specimens of the coal.[1] Shortly afterwards Commander Mitchell, U. S. N., in the U. S. S. *Saginaw*, visited the locality and made a reconnaissance of the entrance to the lagoon and the channel leading to one of the principal outcrops.[2] He took the vessel into the inlet as far as the wider portion, since known as Mitchell Bay, and made an agreement with one of the Indian chiefs to take out a large quantity of coal. He also obtained a few tons before he departed, which he tested on board the vessel, and part of which he forwarded to the San Francisco naval office for testing.

An officer was detailed to direct the natives in their work of getting out the coal. The *Saginaw*, under command of Capt. J. R. Meade, U. S. N., returned in January, 1869, and obtained the coal which had been taken out (variously stated to be from 30 to 80 tons), and which was subsequently submitted to various tests. I have found no official account of these tests, but have frequently heard it asserted that the coal was found to contain fossil resin in such amount as to be an objection to its use on steamers built with a view to using a coal of less volatility, and that the extraordinary heat generated by the combustion of this resin rapidly destroyed the grate bars. At all events, no further attempts are recorded to utilize these coals for the Navy. Captain Bryant describes the coal seam which was worked by Mitchell and Meade as follows:

Opening from the south arm of Mitchell Bay in a southeast direction is Davis Creek, another of those deep channels, one-fourth of a mile wide and connecting with a second bay 2 miles distant. It is on a small arm of this creek that coal has been obtained.

The vein or seam crops out under a rocky point at high-water mark and at right angles with the shore, and extends under the bed of the creek. It has a dip of 10° to the northwest and has been worked by drifting off the slate and removing the coal. This process has been carried forward 50 feet until the covering of slate

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[1] See Senate Ex. Doc. No. 32, Forty-first Congress, second session, 1870, pp. 15-17.

[2] See U. S. Hydrographic Chart No. 225, 1869.

became too thick to be removed with this means of working. The distance between the point and low water is 50 yards and the seam has been opened to that line. The vein of coal has an average thickness of 15 inches. About 100 tons have been taken out. It is of a light bituminous character, burning very rapidly, evolving a great amount of heat, and better adapted for manufacturing purposes than for generating steam with the present style of furnaces.

An examination of the bluff near where the coal has been mined, having its horizontal strata undisturbed, shows the following arrangement: The surface rock is a coarse sedimentary stone 5 feet in thickness, underneath which are 2 feet of shales and slate upon a layer of shale mixed with coal containing resin and burning freely, followed by 8 feet of shale and slate with a slight mixture of coal at the base of the stratum, and below this by a layer of shale 2 feet in thickness overlying a thin vein of coal and resin, which burns with much smoke and leaves little ash. The next stratum corresponds to that from which the coal was extracted and in which fossil leaves and vegetable remains are found. Underneath this and about 4 feet below high-tide mark two seams of coal of a harder kind crop out. These seams are 3 or 4 feet in thickness, and the coal taken from them appears to be the same as that found at Nanaimo, Vancouver Island. An examination of the shores of Mitchell Bay shows evidence that coal exists over a large extent of the surrounding country. * * * Near the shores of Mitchell Bay the disturbance of the strata is so great that the seams can not be followed far without finding them broken. East of Davis Creek the shores rise gradually and continue unbroken, where by sinking a shaft the coal bed may be found at sufficient distance above tide level to render it accessible. The difference of time between high water in Chatham Strait and at the mine is one hour. The mine is 12 miles from the entrance, and the difference between high and low water is 8 feet.

I have cited this account at length because it was made on the spot at the time the mining was done, and I am not quite sure that the place pointed out to me as the site of Mitchell's operations is really the same. In a quarter of a century the exact spot in an almost unexplored wilderness may very well become obscure.

Since that time explorations have been made by private prospectors, who have dug shafts, driven tunnels, or cleared off the surface of the coal seams, but have never had sufficient capital to open a working mine. I believe that we visited all points in the inlet where work of any kind has been done, and the various locations will be described separately.

SEPPHAGEN MINE.

This location is on the southeast arm of the inlet, close to the water's edge. A shaft 8 feet deep had been sunk, which, at the time of our visit (June 9, 1895) was full of water. A winch and small car were there. Three years ago a few tons of coal had been taken out and heaped up near the shaft, which, by the action of the weather, had become reduced to small flakes of slack coal. The seam itself was under water, but was stated to be about a foot thick. The rocks above it were friable sandstones and soft shales. They dip about 30° NW. *Taxodium distichum miocenum* Heer was found among the leaf impressions of the shale. An examination of the vicinity led to the inference that the coal here was a small pocket, soon exhausted.

An analysis of the coal showed:

Analysis of coal from Sepphagen mine, Alaska.

	Per cent.
Moisture	1.66
Volatile matter less moisture	35.40
Coke	31.80
Ash	31.14

The coke was dull and slightly coherent, the ash yellowish; the percentage of sulphur, 0.32.

The owner of this mine had recently died, and the interest was said to be held by his widow and children.

REEF.

Prospectors had found signs of coal in a reef, covered at high water. The seams, if any, were invisible at the time of our visit, and were said to be only a few inches thick. The reef was composed of sandstones and shales, the latter mostly below, both dipping about 35° NW. The shales were very friable, with many mostly fragmentary vegetable remains, but few good leaf impressions. The thickness of the coarse-grained but rather uniform soft sandstones appeared to be several hundred feet. There were occasional concretionary nodules of harder and finer material. The strata, though generally dipping northwest, showed waves in several places and were largely cross-bedded. The shales were variable in hardness, usually soft and friable, in very thin layers, with occasional lignitic nodules but no well-defined coal seams. Among the species of fossil plants collected here the following were identifiable:

Juglans nigella Heer.
Carpinus grandis Unger.
Fagus antipoffii Heer?
Diospyros anceps Heer.
Populus Richardsonii Heer.
Ficus sp.

At another point, on a small islet between two arms from Favorite Bay, Mr. Brightman pointed out a 6 or 8 inch seam of coal, much decomposed at the surface, which was traceable from low-water mark to the base of the bluff. The sandstone is faulted, waved, and everywhere low. The topographic relief seemed everywhere less than 100 feet. The dip is 30° to 45° NW. The arm on which these exposures are shown is the second from the entrance, rocky, and with strong tidal currents, accessible only at slack water.

POINT SULLIVAN.

At Point Sullivan, about 50 feet above tide, a shaft has been sunk 120 feet by James McCluskey and others, with poor results. The outcrop, in a rather soft gray shale, showed about 8 inches of much crushed, slickensided, shaly lignite, dipping 60° NE.; the strike, 60° NW. The shaft is now full of water, and the apparatus is in a state of decay. According to Mr. McCluskey, in the shaft two seams of coal were found, separated by about 6 or 8 inches of hard shale. The first prospector to open this vein was a man named Sullivan. There is a tradition that a still was set up here, and that the celebrated alcoholic fluid called "hoochinoo," which has wrought so much mischief in southeastern Alaska, was first made in the cabins about the Sullivan mine. An analysis of the coal gives:

Analysis of coal from Point Sullivan, Alaska.

	Per cent.
Moisture	0.82
Volatile matter not moisture	21.86
Coke	35.52
Ash	41.80

The coke was somewhat coherent and partly brilliant, the ash reddish. The sulphur amounted to 0.51 per cent.

The coal from this location has been used locally in dwellings adjacent to the mine, but, as shown by the analysis, the quality is wretched.

The shales show numerous leaf impressions, but the matrix is so crushed that it is difficult to get a whole specimen.

MITCHELL BAY.

Opposite the Coast Survey party's camp, June 10, 1895, was observed a small seam, not exceeding 5 inches of coal, with twice as much slate and shale in hard sandstone, dipping 45° N. About ten years ago some one had run a tunnel into this bluff, probably expecting that the vein would become thicker farther in, but as no increase was noted the work was abandoned. A similar seam 4 inches thick and another 4 to 6 inches thick are reported to exist on the southeast shore of the bay, but these, of course, have no commercial value.

MEADE AND MITCHELL SEAM.

This seam as at present exposed is on the face of a low bluff at about 10 feet above high-water mark. We were told that this was the locality where the Indians took out coal for Mitchell. The fact that the old workings visible are tunnels, and not stripped seams, causes a doubt as to the precision of the identification. There are at present two tunnels, 100 yards or more apart. The western tunnel (Mitchell) had been timbered, but is now full of water, and the roof crushed in, probably on account of the decay of the timbering. The visible seam near high-water mark averages 1 foot in thickness, but is much contorted. One hundred feet west of the tunnel the seam turns vertical, bifurcates, and then runs out to a feather-edge. Dip, SE. flat, variable; strike, 25° NE. Above the coal the rock is almost wholly sandstone, without fossils; below, shale, with leaf impressions and vegetable remains. The eastern tunnel (Meade) is in similar rock and is similarly situated, but the strata are somewhat less contorted. The coal is about 1 foot thick. An analysis of coal from the Mitchell vein gives the following:

Analysis of coal from the Mitchell vein, Alaska.

	Per cent.
Moisture	2.37
Volatile matter not moisture	31.73
Coke	30.89
Ash	35.01

The coke is sooty and incoherent, the ash yellowish. The sulphur amounts to 0.47 per cent.

As noted by Bryant and others, in the small fissures of the coal a good many grains of fossil resin or amber were perceptible, and occasionally a small pocket holding a teaspoonful of this yellowish, coarse, powdery material occurred. No large masses of it were noticed, though it is doubtless true, as reported, that they are occasionally found.

BRIGHTMAN AND DE GROFF SEAM.

On a point projecting on the same arm a little farther up is an abandoned tunnel about 100 feet in length. This was put in by Messrs. Brightman, De Groff, and others several years ago. The rocks are nearly horizontal at the entrance, and consist of a rather hard, barren sandstone, inclosing a few feet of shale, divided into an upper and lower part by a seam, about 14 inches thick, of shaly lignite. The shales contain many leaf impressions, among which were recognized *Ficus Alaskana* Newberry, two other species of Ficus, one with a very large leaf; *Carpinus grandis* Unger, *Populus arctica* Heer, *Populus Richardsonii* Heer, *Vitis crenata* Heer, *Taxodium distichum miocenum* Heer, and *Glyptostrobus Ungeri*.

An analysis of the coal gives:

Analysis of coal from Brightman and De Groff seam, Alaska.

	Per cent.
Moisture	2.57
Volatile matter not moisture	55.44
Coke	29.75
Ash	12.24

The coke was dull and partly coherent, the ash drab-colored, the percentage of sulphur 0.89. Several thousand dollars were wasted in the attempt to develop this worthless seam, under the mistaken but common idea that improvement might be expected at a greater depth from the outcrop.

M'CLUSKEY LOCATION.

In a small cove at the head of the left arm of this inlet, farther east than any of the other locations, is an outcrop of coal which has been stripped and prospected by Mr. James McCluskey. There are two principal outcrops of coal. One, at the foot of a small vertical bluff, dips at about the angle of the beach, 25° SE., with a strike 40° NE. The rock above it is a coarse sandstone without fossils. The seam is 18 inches thick, and is visible from low-water to about high-water mark or a little farther. It has been excavated along its face for a depth of 2 feet and a distance of 100 feet. In the beach, and normally covered by the sand and gravel, are several other parallel seams of coal, separated by variably thick beds of shale and slaty sandstone. The upper layer is the best and clearest and does not exceed a foot in thickness. Below this seam is 6 or 8 feet of shale, and then a parallel seam of brown lignite mixed with bright coal and thin leaves of shale. This contains many particles of fossil resin and impressions resembling woody fiber. Owing to the wash over it, the full extent and uniformity of the seam could not be distinctly seen, but it appeared to include about 3 feet, with the central portion somewhat more shaly than the rest. Whether this mass is a local thickening of a seam elsewhere thinner, or part of a uniform bed, can be determined only by more extensive exploration. The rocks about this mine are less disturbed than in the more western portions of the area about the inlet, and the prospect of continuity in the veins is therefore somewhat better.

This outcrop is the only one in the inlet in which work has been recently done, and nearly 100 tons of coal have been taken out. The coal has met with a ready sale locally.

An analysis affords the following data for the upper seam in the beach:

Analysis of coal from McCluskey claim, Alaska.

	Per cent.
Moisture	2.44
Volatile matter not moisture	44.75
Coke	47.93
Ash	4.88

The coke is dull and coherent, the ash of a yellowish color, the percentage of sulphur 0.67.

This coal, as will be noted on comparison, is very much better than any of the other Kootznahoo coals analyzed. The ash is less than one-third as much as the least amount noted in any other coal from this basin, and the proportion of fixed carbon is considerably greater, while the proportion of sulphur is not excessive. It has been used acceptably on some of the small steam vessels which ply in the archipelago. As a rough test, some sacks of it were turned over to the engineer of the *Patterson's* steam launch with a request that he would see what results could be had from it. The launch is No. 18, with coiled tubular boilers. About an hour's steaming was done. The engineer reported that the coal burned well, developed about three-fourths the steaming power of the Wellington (B. C., Cretaceous) coal usually used, and was decidedly better than the Comox (B. C.) coal.

Comparison of Kootznahoo coals.

Mines.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
McCluskey (114)	2.44	44.75	47.93	4.88	0.67
Sepphagen (115)	1.66	35.40	31.80	31.14	0.32
Point Sullivan (116)	0.82	21.86	35.52	41.80	0.51
Mitchell (117)	2.37	31.73	30.89	35.01	0.47
De Groff (118)	2.57	55.44	29.75	12.24	0.89
Nanaimo, B. C	2.98	32.16	46.31	18.55	1.73
Mount Diablo, Cal	14.69	33.89	46.84	4.58	4.37

LOCALITIES WEST OF THE ALEXANDER ARCHIPELAGO, BETWEEN CAPE SPENCER AND COOK INLET.

LITUYA BAY.

Mr. Henry Boursin[1] states that good-sized veins of lignite have been found at Lituya Bay, though no attempt has been made to work them. The croppings reveal a light-weight, glossy-black lignite, which breaks with a conchoidal fracture and burns quickly, leaving a small percentage of white ashes.

The exact locality in Lituya Bay is not stated. On a visit to that locality in 1874 I made the following notes:

"*Beds of Lituya Bay.*—North of the Alexander Archipelago, Cenozoic strata are first reported from Lituya Bay, where they were observed, and a fossil pecten collected at a height of 200 toises, by the naturalists of La Perouse's party. In May, 1874, while making a reconnaissance of the bay, W. H. Dall landed on Cenotaph Island, which appeared to be chiefly composed of the ordinary marine Miocene sandstones, rather soft, but not at this point fossiliferous. This island lies directly in the trough of this extraordinary bay, and is remarkable in that it shows no

[1] Eleventh Census, Report on the Population and Resources of Alaska, 1893, p. 230.

evidences, either by erosion or in the presence of erratics, of having been glaciated, which, if the bay had ever been filled with ice, must have happened. It would seem as if only a very small amount of erosion would have been sufficient to remove the whole of the relatively soft material of which this small and rather high islet is composed. The mass of the material on the beaches and brought down by the ice from the numerous enormous glaciers which discharge into the bay appears to be schistose, or syenitic, the comparatively narrow strip of relatively lowland and foothills in front of the main range parallel with the coast probably containing all the Cenozoic beds remaining there. On the main shores of Lituya Bay the basal rocks appeared to be massive syenite or granite overlain by stratified mica slates, above which was clay-slate with very obscure traces of fossils, and lastly, coarse sandstone and conglomerate, probably of Miocene age, but from which no fossils were collected. The stratified rocks seem conformable with one another and dip to the northwest at angles of from 15° to 75°. Their surfaces showed no traces of glaciation, though these, if ever present, might have weathered away."[1]

These sandstones with the large Miocene pectens are probably identical with the Astoria sandstones of Oregon, the Crepidula bed of the section at Zachareffskaia Bay, Unga Island, Alaska, and the Nulato sandstone of the Yukon Valley. These beds overlie the lignitiferous strata wherever the section is complete, and from their presence at Lituya Bay there is no reason to question the assertion that seams of lignite also occur there.

YAKUTAT BAY.

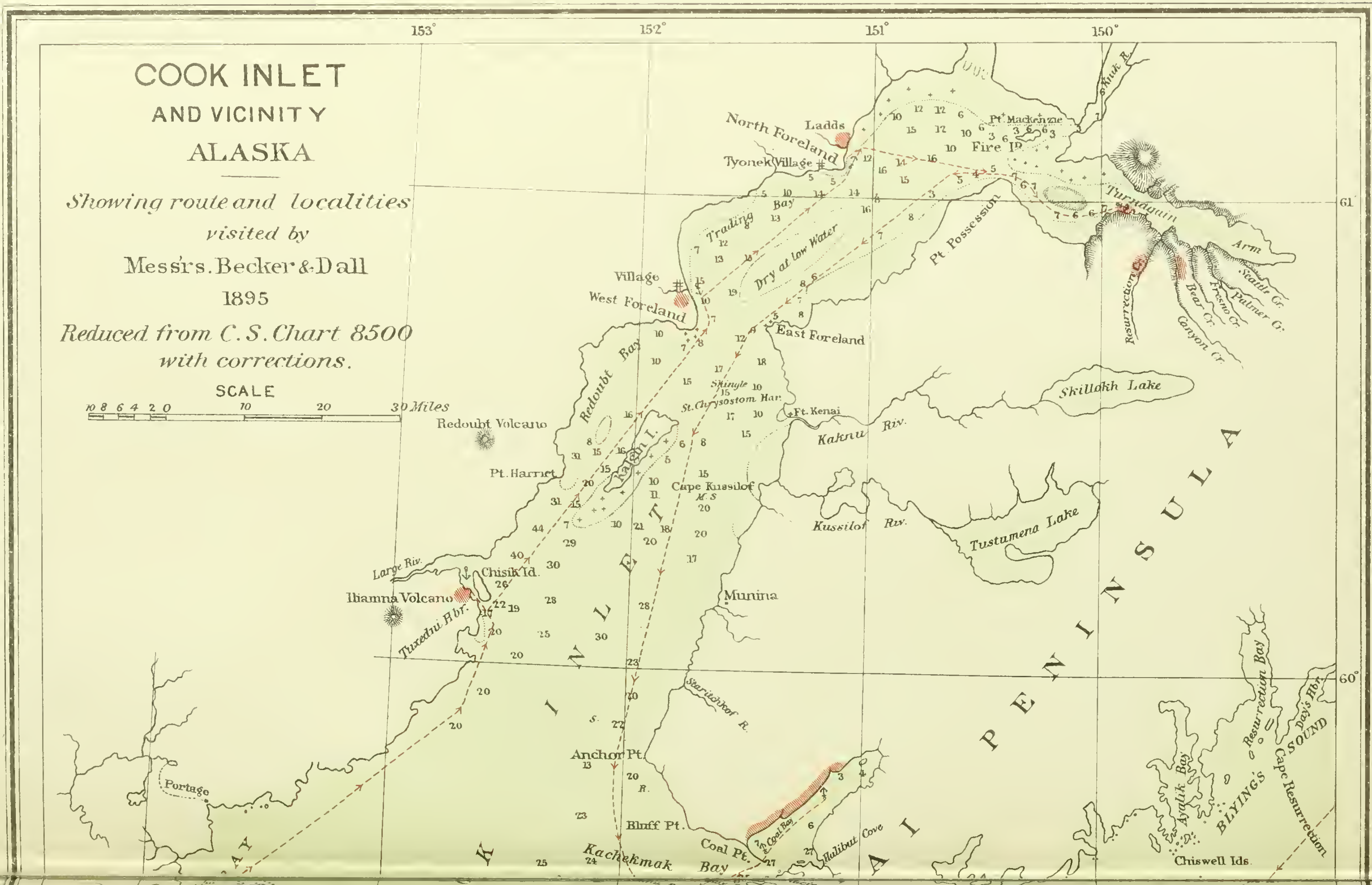
Near Disenchantment Bay, on the east shore of Yakutat Bay, according to Boursin (op. cit.), are a number of seams of black lignite on which several shallow shafts have been sunk. The coal is said to be of good quality and the seams large enough to be profitably worked. Mr. De Groff, of Sitka, and Lieutenant Emmons were at one time interested in this claim, and the former told me that the exact situation of the principal shaft was the same as Camp No. 2 of Professor Russell's St. Elias expedition.[2] The aggregate thickness of the coal seams at this locality is stated to be as much as 5 feet. Owing to the impossibility of obtaining transportation to either Lituya Bay or the east shore of Yakutat, neither place was visited during the summer of 1895, and I was unable to get hold of any specimens of the coal.

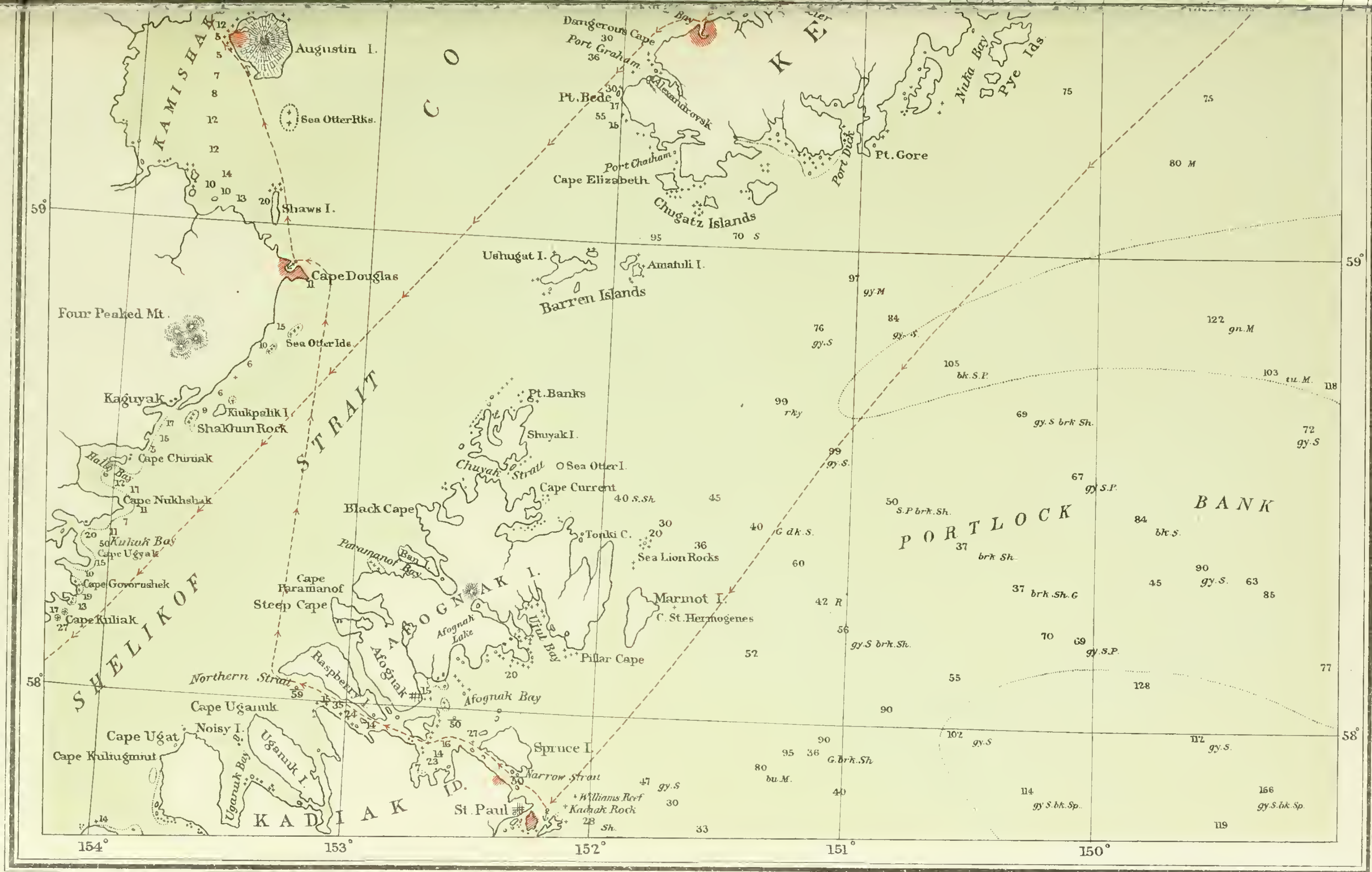
LOCALITIES IN COOK INLET.

This fine sheet of water extends inland more than 200 miles, and has a width near its entrance of over 50 miles. The western shores are formed by Alaska Peninsula and the eastern by Kenai Peninsula, which separates the waters of the inlet from those of Prince William

[1] Geology of Alaska: Bull. U. S. Geol. Survey No. 84. 1892. pp. 235-236.

[2] An expedition to Mount St. Elias, Alaska: Nat. Geog. Mag., Vol. III, 1891, p. 85.


COOK INLET
AND VICINITY
ALASKA
Showing route and localities
visited by
Messrs. Becker & Dall
1895
Reduced from C. S. Chart 8500
with corrections.
SCALE
10 8 6 4 2 0 10 20 30 Miles
153°
152°
151°
150°
61°
60°
North Foreland
Ladds
Tyonek Village
Pt. Mackenzie
Fire ID.
Turnagain Arm
Trading Bay
Dry at low Water
Pt. Possession
Resurrection Cr.
Bear Cr.
Fresno Cr.
Palmer G.
Seattle Cr.
Canyon Cr.
Knik R.
Village
West Foreland
East Foreland
Redoubt Bay
Redoubt Volcano
Shingle
St. Chrysostom Har.
Ft. Kenai
Kaknu Riv.
Skilakh Lake
Pt. Harriet
Kalgin I.
Cape Kussilof
Kussilof Riv.
Tustumena Lake
Large Riv.
Chisik Id.
Iliamna Volcano
Tuxedni Hbr.
Munina
Staritshkof R.
Anchor Pt.
Bluff Pt.
Coal Pt.
Coal Bay
Halibut Cove
Kachekmak Bay
Portage
Chiswell Ids.
Ayalik Bay
BLYING'S SOUND
Resurrection Bay
Day's Hbr.
Cape Resurrection
COOK INLET
KENAI PENINSULA



Augustin I.
Sea Otter Rks.
Shaws I.
Cape Douglas
Four Peaked Mt.
Sea Otter Ids.
Kaguyak
Kiukpalik I.
Shakun Rock
Cape Chiniak
Cape Nukhshak
Kuliak Bay
Cape Ugyak
Cape Gororushek
Cape Kuliak
SHELIKOF
STRAIT
Dangerous Cape
Port Graham
Pt. Bede
Alexandrovsk
Port Chatham
Cape Elizabeth
Chugatz Islands
Port Dick
Pt. Gore
Nuka Bay
Pye Ids
Ushugat I.
Amatuli I.
Barren Islands
Pt. Banks
Shuyak I.
Chuyak Strait
Sea Otter I.
Cape Current
Black Cape
Paramanof Bay
Tonki C.
Sea Lion Rocks
Marmot I.
C. St. Hermogenes
Cape Paramanof
Steep Cape
AFOGNAK I.
Afognak Lake
Ujut Bay
Pillar Cape
Northern Strait
Raspberry I.
Afognak
Afognak Bay
Cape Uganuk
Noisy I.
Cape Ugat
Cape Kuliugmiut
Uganuk I.
Uganuk Bay
KADIAK ID.
Spruce I.
Narrow Strait
St. Paul
Williams Reef
Kadiak Rock
PORTLOCK BANK
59°
58°
154°
153°
152°
151°
150°
JULIUS BIEN & CO. LITH. N.Y.

Sound. The strata of the Kenai formation, which carry the Tertiary coal of Alaska, take their name from this peninsula, on which they are the conspicuous rock series for hundreds of square miles. The backbone of the Kenai Peninsula is formed by rugged mountains of older, mostly crystalline or volcanic rocks, with many glaciers. The southwestern end of this range comes to the coast near the entrance of the inlet, and the mountainous tract is here penetrated by a number of bays and harbors. Northward from it the deep bay of Kachemak penetrates far into the peninsula, and the Kenai beds on its southeast side are much broken, upturned, and faulted. On the opposite side of the bay they are, on the contrary, little disturbed and have but moderate dip angles, or large and gentle waves of inclination. Owing to these conditions coal mining on the northwest side of Kachemak Bay has an entirely different prospect of success from that to the south and east of the bay.

PORT GRAHAM.

This harbor, also known as English Bay, was first described by Portlock in 1786,[1] though it had previously been known to the Russians. Portlock says:

> We landed on the west side of the bay, and in walking around it discovered two veins of kennel coal situated near some hills just above the beach, about the middle of the bay, and with very little trouble several pieces were got out of the bank nearly as large as a man's head. * * * In the evening we returned on board and I tried some of the coal we had discovered and found it to burn clear and well.[2]

Portlock made a chart of the bay, and named the cove under Dangerous Cape, where he saw the coal, "Coal Bay." He gives a view of the cove, in which, however, the height of the hills is much exaggerated. Later on the Russians established a trading post, which was called Alexandrovsk, on the opposite side of the bay. The presence of a large native village and the vicinity of the otter hunting grounds were probably the deciding reasons for this location. About 1866 the Russians had decided to move their village over to the better location of Portlock, and had a number of log houses set up and others partly built at the time of the transfer of the territory to the United States. About 1852 the Russian American Company began to make use of steamers, and their attention was called to the coal described by Portlock and subsequently reported upon by Doroshin and Wossnessenski.[3] Doroshin was a mining engineer detailed to examine the mineral resources of the colony, and under his supervision a shipload of the coal was obtained and taken to San Francisco to be tested. The Russian American Company hesitated to undertake mining operations on its own account, and, having entered into relations with certain Californian capitalists, in 1852 an establishment at Kadiak was authorized by

[1] A Voyage to the Northwest Coast of America, pp. 102–110. 4°. London, 1789.

[2] Op. cit., p. 108.

[3] See Grewingk, Beitrag zur Kenntniss NW.-Küste Am., 1850, pp. 39-41; and Wrangell. in Baer and Helmersen, Beiträge, I, pp. 168-170.

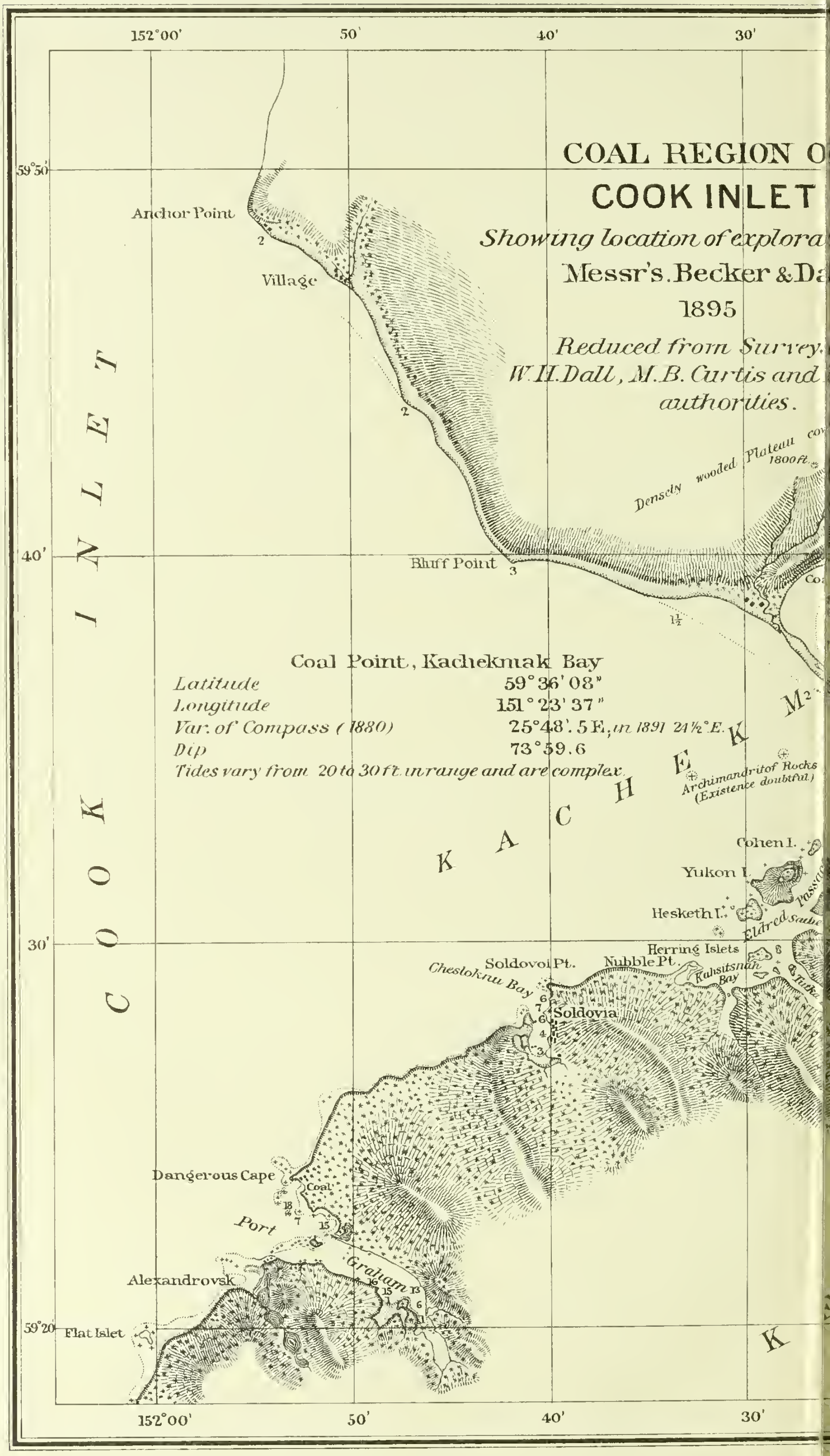
which the American Company was permitted to put up ice for the California market. After various tests had been made, the same company was empowered, on raising the necessary capital, to open the coal mines at Port Chatham.

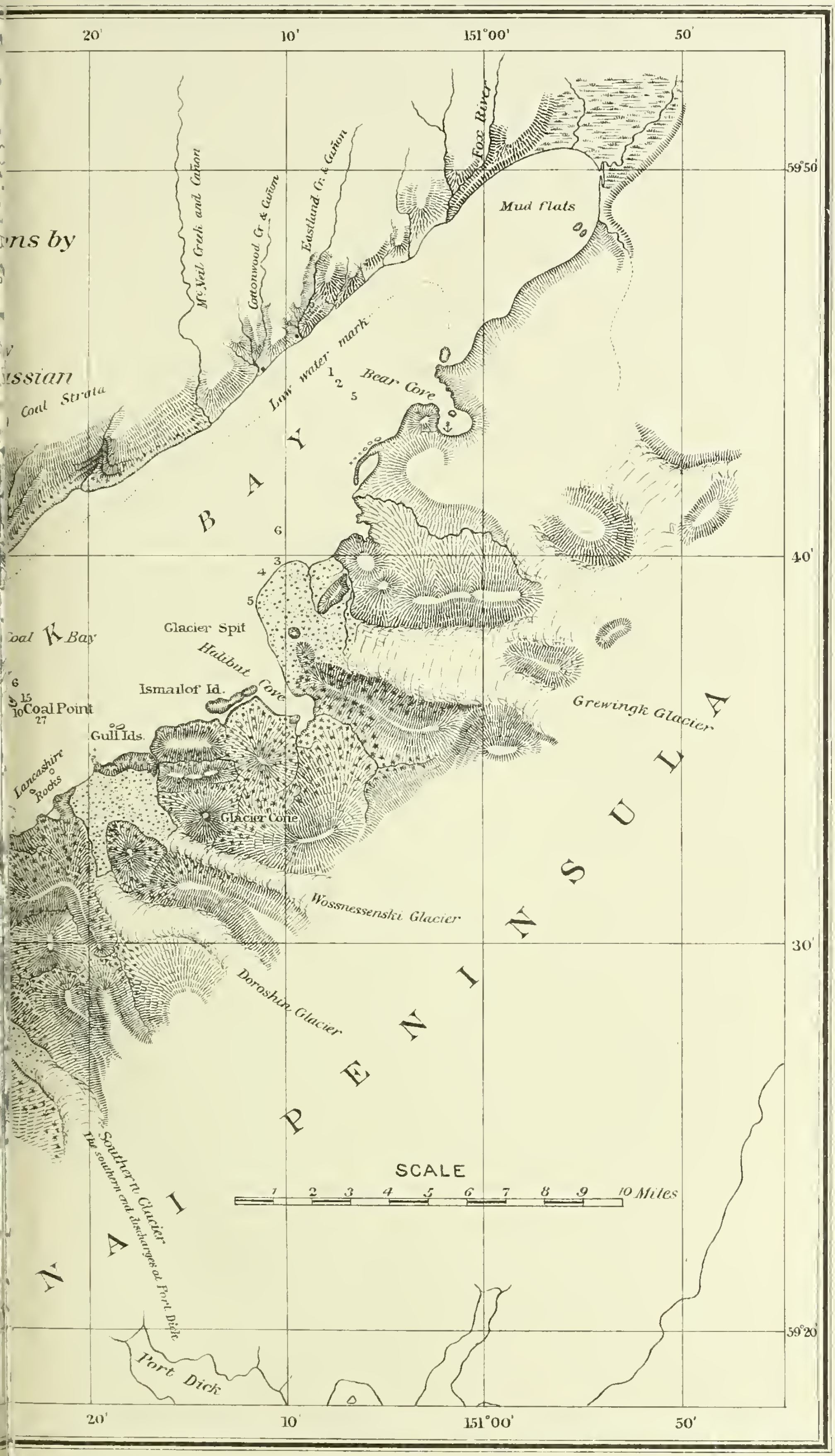
In April, 1855, the bark *Cyane*, Captain Kinzie, left San Francisco for Port Chatham, where miners and mining machinery were landed. It is difficult at this date to obtain information in regard to these mining operations, which continued some ten years and supplied the Russians with a certain amount of coal which was used on their steamers. As better coal became available by the opening of mines in British Columbia, Oregon, and Puget Sound, the Port Chatham coal became less necessary, and with the transfer of the territory to the United States the mine was finally abandoned. The disturbed condition of the beds, already referred to, interrupted the mining operations by frequent faults, and it was complained that an excess of sulphur in the coal made it destructive to boiler tubes and grate bars. Nevertheless, like the Mount Diablo coal of California, which was even more objectionable, and for similar reasons, the Port Chatham coal for a time served a useful purpose. In 1880 I visited the site of the workings and found the tunnel inaccessible from the water which partially filled it and the caving in due to the rotting of the timbering. The works had evidently been of a primitive kind, as there were no permanent buildings and not even a pier for shipping the coal. Only a few pieces of worn-out, rusty machinery and the tunnel in the bluff at the top of the beach remained to show that any work had ever been attempted here. I have seen statements that an extensive stone pier and costly buildings had been erected here and large sums of money lost in the attempt to utilize the coal, but, apart from the intrinsic improbability of such foolish doings, no evidence of the truth of the statements was furnished by the locality itself at that time. It is probable that the abandoned log houses already mentioned became connected with the abandoned coal mine in the mind of some visitor, and thus started the rumor, though there was really no connection between them. At present there is no coal visible at the surface, and in view of the better conditions prevalent to the northwest the existence of coal seams at Port Chatham has only an historical interest. I add a few geological notes.

It was at this place that Furuhjelm collected a large number of plant remains, which formed the chief basis of Heer's report.[1] These beds lie unconformably in depressions in felsitic rock and greenstone, nearly horizontally, as follows:

1. Humus and turf.
2. Sandstone with pebbles.
3. Bluish sandy clay with pebbles.
4. Plastic clay.

[1] Flora fossilis Alaskana, von Oswald Heer: Kongl. sevensk.-Vet.-Akad. Hand'. Bd. 8, No. 4, Stockholm, 1869.


COAL REGION O
COOK INLET
Showing location of explora
Messr's. Becker & Da
1895
Reduced from Survey
W. H. Dall, M. B. Curtis and
authorities.
Coal Point, Kachekmak Bay
Latitude 59° 36' 08"
Longitude 151° 23' 37"
Var. of Compass (1880) 25° 48'. 5 E., in 1891 24½° E.
Dip 73° 59.6
Tides vary from 20 to 30 ft. in range and are complex.
COOK INLET
KACHEKMAK
152°00'
50'
40'
30'
59°50'
40'
30'
59°20'
Anchor Point
Village
Bluff Point
Densely wooded Plateau
1800 ft.
Archimandritof Rocks (Existence doubtful)
Cohen I.
Yukon I.
Hesketh I.
Herring Islets
Eldred
Soldovoi Pt.
Nubble Pt.
Chestokna Bay
Kahsitsnah Bay
Soldovia
Dangerous Cape
Coal
Port Graham
Alexandrovsk
Flat Islet



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5. Gray, fine-grained sandstone, 5 to 7 inches thick.
6. Lignite, 9 to 11 feet thick, including interleaved shale.
7. Laminated clay-shale, partly bituminous.
8. Light-gray, rather soft limestone, with few plants.
9. Laminated clay.
10. Hard limestone, with many plant impressions.
11. Brecciated porphyry and greenstone in limy matrix.
12. Felsite and greenstone base.

The coal is black and brilliant, with conchoidal fracture, resembling that of Disco in Greenland. It contains occasional grains of honey-yellow amber, rarely more than a centimeter in diameter.

The plants are all terrestrial or fresh-water species. One of the most common is a species of *Trapa* represented by many of its fruit. With them were found *Unio* (*Margaritana*) *onariotis* Mayer, a species probably related to *Margaritana margaritifera* L.; *Amnicola abaria* Mayer; and *Melania* (*Goniobasis?*) *furuhjelmi* Mayer, together with elytra of a beetle described by Heer under the name of *Chrysomelites alaskanus*. Among the plants are both Coniferæ and broad-leaved trees, the total number of species amounting to forty-four. The deposit appears to have been formed at the bottom of a lake. The leaf-bearing strata crop out below the level of the sea and are accessible only at extreme low water. They dip slightly to the northward.

THE KENAI PLATEAU.

This region includes the area west of the Kenai Mountains and extending along the eastern side of Cook Inlet, between Kachemak Bay on the southwest and Turnagain arm at the northeast. This area is more than 25 miles wide and over 80 miles long, thus covering at least 2,000 square miles. The land comes to the sea in steep bluffs, generally with only a narrow beach at their base. The height of the bluffs is greatest at Bluff Point, near the entrance to Kachemak Bay, where it reaches 1,800 feet within half a mile of the water. Thence northeastward the strata describe a series of gentle, enormously extended waves, plainly visible from vessels sailing by the coast. The height of the plateau grows gradually less; at Cape Kassiloff the coal seams finally sink below the sea level, and on the south shore of Turnagain arm the land rises less than 50 feet above the sea level. The upper surface is more or less undulating, cut by numerous streams which form narrow, deep valleys in the soft Tertiary rocks, and, according to native reports, sometimes rise in large, shallow lakes which receive the drainage from the glaciers of the Kenai range. Nearly all this area is heavily wooded with spruce and larch, mixed with poplar, alder, and willow along the watercourses. Entrance to some of the larger streams may be had at high water, but the only harbor is at Kachemak Bay. The Kenai formation containing the coal probably underlies the entire area of the plateau, but again it is only at Kachemak Bay that the strata are elevated to their greatest height and the lower and more densely consolidated coal seams are brought near the surface. Off Anchor Point, we were informed, at extreme low water, fossil "oysters" (Inoceramus) are abundant. It is, therefore, probable that the Kenai beds are directly underlain by the same Cretaceous rocks which are abundantly distributed on the west shore of Cook Inlet, especially at Chasik Island. The conditions of time, weather, and transportation were such that we were unable personally to verify this information. A few notes on the coast north of Anchor Point will now be given, and then the beds at Kachemak Bay may be taken up.

If the indications of Wossnessenski (in Grewingk)[1] are correct, there would seem to be a succession of about four gentle folds from Port Graham to Cape Kassiloff, a distance in a northerly direction of some 70 miles. The lignite beds crop out at many places along the western shore of this area. At Anchor Cape (Kasnatchin), the northern head of Kachemak (or, as it is sometimes called, Chugachik) Bay, the coal is under water, but rises northward with the flexure of the strata. At Anchor Cape, Furuhjelm obtained fossil teredo-bored bituminous wood. At Cape Nenilchik, near a small native settlement, the lignite beds are about 35 feet above the sea, and at one place burned for many years.[2] From this locality also many fossil plants have been obtained. The leaves occur in a soft, pale-gray clay-slate, which can be cut with the knife, but which, where burned, becomes hard and red. Still farther north on the same shore, at Fort Kenai, Captain Howard, of the Revenue Marine, obtained several fossil plants, which have been described by Newberry.[3] Five of these were new, which raises the number of species actually obtained on the Kenai Peninsula to 58.

At Cape Staritchkoff two parallel beds of coal are visible for a long distance. The lower one is about 112 feet above the beach and is separated by 9 to 12 feet of sand and clay from the upper coal bed, above which the bluff rises 40 to 70 feet higher. At Cape Nenilchik the upper bed covers about 18 feet of fine, yellow sand and is separated from the lower bed by about 20 feet of sand and clay. At this locality an Anodon (*A. athlios* Mayer) was found in making Furuhjelm's collection.

I defer any discussion in regard to their geological age until the other localities at which this flora occurs have been referred to. The Kenai beds, from the number of their contained species and their excellent illustration by Heer, will always be regarded as typical for the group.

KACHEMAK BAY.[4]

This bay has been known since the earliest explorations of the Russians in the last century carried them into Cook Inlet. If advantages

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[1] Beitrag, 1850, Pl. III, p. 39.

[2] This burning was first noticed in 1829.

[3] Proc. U. S. Nat. Mus. 1882, Vol. V, pp. 502–514.

[4] The native name of this bay is derived from the word *Ka*, meaning water; *chek*, bluff or cliff, and the intensive suffix *mak*, meaning large, high, or great. The whole word, *Ka-chek-mak*, may be translated Highcliff Bay. This name was used in the first published and subsequent charts of the bay until 1892, when the form used in this report became obligatory in Government publications through the action of the Board on Geographic Names.

for navigation had been the ruling motive, doubtless the Russian establishments would have been located here, but other reasons connected with their business outweighed this. As no large streams enter the bay, few salmon are found in it, and it is rather remote from the otter grounds. Therefore, excepting the little village of Seldovia, near the entrance, there were no native settlements in the bay, and, until after 1880, no strong reason why there should be any. Some confusion has been caused on the charts by ill-advised attempts to apply synonymous names to different parts of it. The native name of Kachemak applies to the bay proper, above a long sand spit which defends the anchorage. Chugachik Bay is the native name for Prince William Sound. Natives traveling to the sound from the inlet could make a portage from the head of Kachemak Bay over to the seacoast, thus saving a long and dangerous canoe journey. From its use as part of the route to the true Chugachik Bay, and by a corruption of the native word expressing this, the Russians came to call Kachemak Bay "Chugachi," thus having the same name for two large bays within 100 miles of each other. This, of course, is very objectionable, and the name Chugachik should be kept for the bay to which it really belongs (i. e., Prince William Sound) or rejected from geographical nomenclature altogether. The name Coal Bay is also not free from objections, as it was the first name applied by Portlock to the anchorage in Port Graham, near the coal beds there, and there is another Coal Bay, not very distant, on the south shore of Alaska Peninsula. Kachemak Bay was first visited by me in 1880, and the following notes, taken at the time, were included in my summary of the Kenai beds in Alaska in 1892:[1]

"Northward from Port Graham is the entrance to a large inlet, Kachemak Bay, on the southern side of which four glaciers extend nearly to the sea level. The rocks on this side of the inlet, as observed by Dall in 1880, are schistose or crystalline, but the northern shore is of a different character. It is formed by the bold edge of a plateau which, in latitude 59° 42′, rises to about 1,800 feet at a distance of 2 miles from the shore. At the shore near Coal Point (a low, sandy spit, behind which an anchorage may be had) the bluffs rise abruptly about 200 feet. The line of bluffs extends north and east for some 30 miles, and the Miocene plant beds crop out at many points. In some places the bluffs come down to the beach; in others there is a small talus between them and the water, which is extremely shallow for some distance out. The lignite beds dip slightly to the northward and are intercalated between sandstones and shales with fossil plant remains, and conglomerates or coarser sandstones above. The largest seam of coal which was observed near Coal Point was about 7 feet thick, with a few thin streaks of shale in it. It is bright, clean to handle, light, and tends to break up in cubical fragments when dried. It resembles anthracite in appearance, but not in weight. Farther up the bay

[1] Bull. U. S. Geol. Survey No. 84, 1892, p. 237.

better outcrops were reported, and the coal was pronounced good by the engineers of Sir Thomas Hesketh's yacht *Lancashire Witch*, who used it for steaming purposes in 1880, and also found it to burn well in an open grate in the cabin.

"From this locality most of the plants described from Port Graham by Heer were identified from Dall's collection by Lesquereux[1] and also nine others, making 53 species."

The chart included in this report (Pl. LI) will give a better idea of the character of this fine bay than could any verbal description. It is taken from the Coast Survey chart of 1880, which was based on a manuscript Russian reconnaissance by Archimandritoff, corrected in part by a triangulation which extended from the long spit to the terminal moraine of the Grewingk glacier.

On the occasion of our present visit, in 1895, I found that M. B. Curtis, esq., in charge of the mining operations of the North Pacific Mining and Transportation Company, had occupied his leisure in correcting the shore lines of the upper part of the bay by triangulation with a field transit and chain measurements. With his permission I secured a copy of his work, which greatly improves the accuracy of the chart and enables the precise location of the various mining claims to be indicated.

Above the long spit the shores of the bay are formed on the south and east by schistose and crystalline rocks. To the west and south of Nubble Point, especially east and west of Seldovia and on the north shore of Port Graham, the sandstones and shales of the Kenai formation are found unconformably overlying the crystalline rocks, in depressions or bays of the latter, and more or less disturbed by later changes of level. The coal of Port Graham and sundry small seams which have been reported near Seldovia on this side of the bay are therefore accounted for. The following notes were taken at Seldovia July 31, 1895.

The rocks about the harbor are schistose and much contorted. In some of the gaps between the projecting points northwest and southeast of the harbor are patches of what appear to be Tertiary (Kenai) beds, which here lie nearly horizontal, abutting unconformably upon the schists. One such patch southeast from the entrance to the harbor shows a dark, carbonaceous streak. Northwest from the harbor a coal seam is reported about 5 inches thick. A piece of coal said to be from this seam, which was shown us in the village, was picked up on the beach below the bluff and is compact, glossy, and of conchoidal fracture. These small seams with a very limited area of distribution have, of course, no economic value, but are mentioned because such deposits are often made the foundation for exaggerated statements by ignorant or overenthusiastic persons.

On the north shore of the bay, from Anchor Point to the mud flats

[1] Contributions to the Miocene flora of Alaska, by Leo Lesquereux: Proc. U. S. Nat. Mus. 1882, Vol. V, pp. 443-449, Pls. VI-X.

at the head of the harbor, a distance of about 35 miles, the bluffs are almost uniformly high, and composed of sandstones, shales, hard clay beds, and seams of lignite. From Anchor Point to the long spit (Coal Point), though a number of coal seams exist, their situation is such that they could not easily be worked economically. There is no protection for vessels. The water for some distance offshore is shoal, and the bottom is reported to be dangerous from the presence of scattered masses of rock. The seams of this part of the bluff could only be made available by a railway, which might be carried along the foot of the bluff to Coal Point, the expense of which would seriously handicap the miners compared with those whose works were situated inside the harbor. We were informed that a number of claims existed on the seams west of Coal Point, mostly belonging to Russian creoles of the settlement at Nenilchik, some miles north of the bay; but no one seemed to know whether any work had been done on these claims, or exactly what their limits are, and in the absence of their owners no data could be gathered. It appeared clear, however, that as far as the character of the coal seams and coal is concerned they resemble in every respect the other portions of the same series northeast of Coal Point.

BRADLEY SEAM.

Beginning at the southwest, immediately above the long spit, the first location is that which I examined in 1880, as previously described. There are several seams close together, aggregating about 7 feet, separated by strata of leaf-bearing shale. The lowest of the coal seams is the best and thickest. This seam shows about 18 inches of clear coal, which is nearly the lowest of all seams exposed on this side of the bay, and runs from the bluff obliquely across the beach as far as it could be followed at low water. As nearly as could be determined, the average dip was about 15° N., but this changed and became less steep gradually along the seam. This seam is said to be the one explored in February, 1888, upon which the Alaska Coal Company's entry was founded, and on which a tunnel, now caved in, was run by Mr. J. A. Bradley, who has devoted much energy and some years of labor to the development of these mines. For convenience in discussing the different coal seams, I shall refer to this one as the Bradley seam. Its exact location is on the beach a short distance southwest of the mouth of a small river, the first which falls into the bay above the spit as indicated on the chart.

The coal is more compact, more disposed to cubical fracture, and more glossy when broken than that of the geologically higher veins farther up the bay. For the use of the small steam tug *Kodiak*, upon which we were traveling, our party broke out about 15 tons of this coal with crowbars, and we depended upon it entirely for steam purposes and galley fuel during the rest of the voyage to the Shumagins. The shore in front of the mine, as is the case the whole length of the bay, runs off shoal for a mile or more, which is dry at low water, the range of tide in the bay sometimes exceeding 30 feet. Under present conditions coal can be lightered off only at favorable stages of the tide. Near the eastern end of the spit, however, deep water comes close to the beach with a perfectly protected anchorage, and the plans for utilizing the coal of this bay which I have heard discussed have almost uniformly included a railway out upon the spit to the deep water referred to. This is obviously the most convenient plan, and would greatly reduce the amount of wharf which otherwise would have to be constructed. Of course any corporation which owned the spit would possess great advantages over any other shippers of coal. Mr. Bradley states that the teredo, so destructive at Sitka and other points in Alaska, is not found in the bay, and I observed no traces of its work on driftwood, etc. If this exemption is a permanent one, it will be of a good deal of importance from a pecuniary standpoint.

Proceeding northeastward, the bluffs[1] which form the northern shore are from time to time interrupted by the canyons of small streams which enter the bay obliquely to the shore line, almost all of them trending inland to the north or eastward of north. At their mouths narrow strips of beach land are found; almost everywhere else the sea at high water comes up to the foot of the bluffs. The steep sides of these canyons give good sections of the strata to the prospector, and of these advantage has been taken. Three of them are the site of prospective coal mines on which some exploration has been done. There are in all some half dozen principal canyons, besides some smaller ones. The southernmost locality where mining has been done is called McNeil Canyon (see map, Pl. LI, facing p. 786). It was from beds in this locality that the coal tested by Lieut. R. P. Schwerin was obtained.

CURTIS SEAM.

Beginning to the westward and working up the bay, at a point a few hundred yards southwest of McNeil Canyon, Mr. Curtis has run two short tunnels into the bluff about 45 feet above the beach. The clear coal is here 4 feet 7 inches thick, with about 6 inches of iron-stained sandstone above it and a thick, adhesive, gray clay below. This seam would require timbering, to avoid caving in, if worked to any extent. Above this are three other seams, separated by thick beds of clay or soft sandstone. One of these, the lower seam, is nearly 4 feet thick; the others are somewhat thinner. The strata are here nearly horizontal. The coal, though lighter than the Bradley, is fairly compact, with a dull fracture, no visible pyrite, occasional thin lenses of sand or shale, and a tendency to break up cubically. This will be referred to as the Curtis seam.

M'NEIL CANYON.

From McNeil Canyon, next above, in 1891, Lieut. R. P. Schwerin, U. S. N., on behalf of New York parties, prospected for coal, and took

[1] Pl. LII gives a general view of these bluffs.

COAL BEDS, CACHEMAK BAY.

out 200 tons of it, which was taken to San Francisco and in September, 1891, was submitted to a series of tests which will be referred to later. This expedition left no permanent works or buildings.

The next locality is the Cottonwood Canyon, where some prospecting has been done and a log house built at the delta as a shelter for the prospectors and to hold the location. The exploration here has not proceeded far.

EASTLAND CANYON.

Next above is Eastland Canyon, where more work has been done than at any other single locality on the bay. The engineer in charge, Mr. M. B. Curtis, offered us every hospitality in his power, and showed us everything which was to be seen.

A small tramway leads back several hundred yards into the canyon, and at a height of 270 feet above the tide we found a vein 2 feet 4 inches thick of clear coal, and associated with it alternate smaller seams of coal and clay, or "bone," the total thickness of the series being 6 feet. The rocks here are nearly horizontal, and comprise sandstone, whitish clay containing large waterworn bowlders, shales, and lignite, the upper part covered with from 5 to 10 feet of reddish gravel. The bluffs attain a height of from 600 to 800 feet, the land behind them reaching 1,800 feet. These explorations were begun in December, 1894, by the North Pacific Mining and Transportation Company, under the supervision of Mr. Curtis. About 300 tons had been taken out and sent to San Francisco for trial, and another cargo was to be shipped shortly after our visit. Mr. Curtis had only a few men employed, and the work he was doing was of the nature of exploration. The development of the property, he stated, would depend upon the results of experiments with the coal.

The parties actively interested at present in these coal deposits are two corporations. The older is the Alaska Coal Company, incorporated December 26, 1889, under the laws of California, with a capital stock of $2,000,000, distributed among 89 stockholders in shares of a par value of $10 each. In 1891 the officers were W. H. Eastland, president; J. A. Bradley, vice-president; S. M. Eastland, secretary, and the California Safe Deposit and Trust Company, treasurer. In 1895 Dr. C. H. Walker was president. The offices of the company are at 216–218 California street, San Francisco. They have expended about $50,000 in exploration.[1] The other corporation is the North Pacific Mining and Transportation Company, organized under the laws of California in October, 1894, Joseph Rosenthal, president; Theodore Fox, vice-president; E. A. Parish, secretary; Leander Shores and S. Joseph Theiser, directors. The capital stock is 300,000 shares, of a par value of $10. The office of the company is at 19 Montgomery street, San Francisco. The expenditure of this company to October, 1895, aggregated $42,000, and

[1] Most of the above information is derived from the company's prospectus, 24 pp. 8°, with map and two lithographic plates, issued at San Francisco in 1891.

I was verbally informed that 650 tons of coal in all had been taken out from the works at Eastland Canyon.[1]

I received the impression that these two corporations, if not composed of the same members throughout, were at least not competitors, and were sustained chiefly by capital from a common source.

A test made by the Southern Pacific Company was of the nature of an investigation into the utility of the coal for railway purposes. It was, I am informed, determined that the liability of the coal, while burning under a forced draft, to throw off large ignited cinders, made it, if used for railway purposes, dangerous to crops and buildings in so dry a country as California in summer, and this disqualification was decisive.

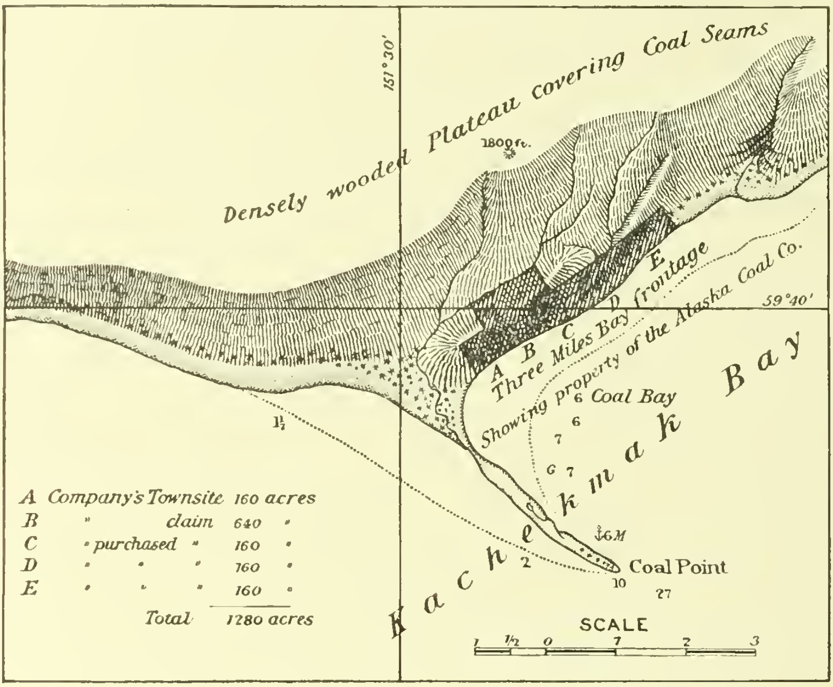

FIG. 23.—Sketch map showing claims of Alaska Coal Company, from their prospectus of 1891.

The two coal companies above described claim at present the long spit and the whole northern shore of Kachemak Bay inside the spit, under various laws or usages. If the bay should become the site of mining operations, a light-house would be needed on the extremity of the spit, and it would therefore be advisable to reserve from entry a certain portion, at least, for Government uses. So far as buildings are concerned, those at present standing are: (1) A house, store, and several outbuildings at the end of the spit, which I was informed were

[1] Information furnished verbally by John A. Bradley, esq., of San Francisco.

the property of Mr. Bradley, or the Alaska Coal Company, of which he is a member, and which were unoccupied at the time of our visit; (2) a number of buildings at the foot of the bluff near the other end of the spit (see A on map, fig. 23, opposite), where it joins the mainland. These are unoccupied and out of repair; they are nominally in charge of Mr. Cooper, of Nenilchik, who visits them occasionally, and are the property of the Alaska Coal Company.

The North Pacific Mining and Transportation Company has two or three buildings, a tramway, and a short pier at the mouth of Eastland Canyon, and houses at the mouth of Cottonwood and McNeil canyons. They also have one or more lighters at the cove named Bear Cove, on the opposite side of the bay, which is better protected than the north shore. These buildings were occupied by Mr. Curtis and his force of employees at the time of our visit. All these houses are log or frame structures, sufficiently substantial for their purposes.

Samples of coal were taken as follows: No. 213, from the Bradley seam; Nos. 218, 219, and 220, from the seams in Eastland Canyon at 270 feet altitude; No. 222, from the Curtis seam. Analyses give the following results:

Analysis of coal from the Bradley seam, Alaska.

[Sample No. 213.]

	Per cent.
Moisture	12.64
Volatile matter not moisture	43.36
Coke	37.14
Ash	6.86

This coal is brilliant at fracture, breaking into cubical fragments when dry, with duller streaks, no visible pyrite, and giving a fine gray ash without clinkers. The coke is dull and noncoherent. The percentage of sulphur in the whole coal is 0.49; of phosphorus pentoxide, 0.021. The ash contains 12.88 per cent of lime and 5.34 per cent of ferric oxide. As the coal was taken out of a part of the beach covered by the sea at high tide, the percentage of moisture may be somewhat in excess of the normal.

Analysis of coal from Eastland Canyon, Alaska.

[Sample No. 218.]

	Per cent.
Moisture	11.72
Volatile matter not moisture	46.50
Coke	34.64
Ash	7.14

The coke is dull and noncoherent, the ash yellowish. In the whole coal the percentage of sulphur is 0.40; of phosphorus pentoxide, 0.69. The ash contains 27.37 per cent of lime and 6.28 of ferric oxide. The coal was dull charcoal-black, with an apparently fibrous structure, breaking into elongated splinters and chips, and giving when scratched a dark reddish-brown streak.

Analysis of coal from Eastland Canyon, Alaska.

[Sample No. 219.]

	Per cent.
Moisture	10.35
Volatile matter not moisture	52.22
Coke	34.58
Ash	2.85

The coke is dull, very slightly coherent; the appearance of the coal resembling No. 218. This specimen was taken from a mass which had been exposed to the weather. The percentage of sulphur is 0.17.

Analysis of coal from Eastland Canyon, Alaska.

[Sample No. 220.]

	Per cent.
Moisture	11.59
Volatile matter not moisture	50.70
Coke	30.84
Ash	6.87

The coke is dull and noncoherent. The percentage of sulphur in the whole coal is 0.22; of phosphorus pentoxide, 0.10. The ash contains 30.86 per cent of lime and 5.17 per cent of ferric oxide.

Analysis of coal from Curtis seam, Alaska.

[Sample No. 222.]

	Per cent.
Moisture	11.67
Volatile matter not moisture	52.37
Coke	21.01
Ash	14.95

The coke is dull and noncoherent, the ash yellowish. The percentage of sulphur in the whole coal is 0.46; of phosphorus pentoxide, 0.132. The ash contains 14.39 per cent of lime and 2.13 per cent of ferric oxide. This coal is one of the highest in the series, and the lightest in proportion to mass of any examined. Its proportion of volatile carbon, sulphur, and phosphorus is appreciably greater than in the coal of the older seams, and the lime and iron less.

In the prospectus of the Alaska Coal Company an analysis by Thomas Price of a sample of coal from their property, probably taken from the Bradley seam or its vicinity, is given as follows:

Analysis of coal from Alaska Coal Company.

	Per cent.
Moisture	8.55
Volatile matter not moisture	32.50
Fixed carbon (coke)	56.00
Ash	2.95

An analysis by Dr. Newberry of coal from Cook Inlet, probably from Port Graham, was furnished the Smithsonian in 1869, as follows:

Analysis of coal from Cook Inlet, Alaska.

	Per cent.
Moisture	1.25
Volatile matter	39.87
Coke	49.89
Ash	7.82
Sulphur	1.20

This specimen had been a long time in hand before it was analyzed and had probably lost part of its original moisture.

A discussion and comparison of the various coals of Kachemak Bay with other Pacific Coast coals and lignites will follow the descriptive part of this report. It may be said here, however, that when the facilities for mining, timbering the works, and shipping the coal are considered, as well as its amount and quality, it is evident that, so far as our present knowledge goes, if the problem of the economic value of these deposits is not decided favorably at Kachemak Bay, the question can hardly be raised for other localities.

LOCALITIES WEST OF COOK INLET.

Along the shores of Alaska Peninsula west and south from Cook Inlet lignite beds associated with plant impressions are not uncommon, and in some places the coal forms seams of tolerable thickness.

Many of the localities have attracted no attention, and those referred to here probably form but a small proportion of the whole number, since the exploration of this coast is still very imperfect.

It may not be inappropriate to state here that in times preceding the Russian conquest amber was regarded as of great value by the natives of this region, a very small bead of this substance being worth in native estimation forty or fifty sea-otter skins, equivalent at present values to some $20,000 of our money. Consequently the localities where it might be found were places of great interest to the aborigines, and the traditions still current are often useful in identifying the presence of beds of this age. A few of these beads are still extant. The largest one known is in my possession. It was obtained from a grave on the island of Kadiak, traditionally regarded as that of a celebrated prehistoric chief of the tribe. It is about 2 inches long, ovate, roughly three-sided, and an inch in diameter. It has been bored for the passage of a suspensory thread, but otherwise is apparently in its original state. It is clear and of a rich wine color, resembling Levantine amber. The surface, though slightly irregular, is polished. Small grains of the same color, too small for use as ornaments, are not rare in the lignite beds of this region.

In mentioning reported localities for the coal-bearing Kenai beds the localities for amber will therefore also be included, as where the latter is found the Kenai formation, from which it is derived, can not be far off.

CAPE DOUGLAS.

This point forms the southwestern point of entrance to Cook Inlet and is one of the localities where it was rumored coal existed. To the westward of the cape is a bight where anchorage may be had. The cape itself is low, with rocks about it, and is composed of mostly horizontal, andesitic flows, more or less interstratified with ash beds containing carbonaceous matter and plant remains. They are somewhat faulted, and the ash beds are often stream-waved and sometimes contain pebbly layers. Among the plants were *Sequoia langsdorffii* (Brgt.) Heer, and fragments of ferns, Equisetum, coniferous leaves, grass leaves and stems, reeds, and other indeterminable vegetable impressions, doubtless of the age of the Kenai formation. The promontory forming the western head of the bay is composed of a very level layer of columnar andesite, about 40 feet thick, with a talus of material derived from it and indications of leaf beds below. The top of both promontories has been moderately glaciated and shows a few erratics. The agency might have been an extension of the glacier whose stream now discharges into the head of the bight, as the grooving points that way. The rocks are a good deal decomposed on the surface, but the influence of the glaciation seems to have been devoted to planing off rather than to scoring. No coal seam of any economic value was observed in this vicinity.

AMALIK HARBOR.

This locality is situated on the south shore of the peninsula, in about latitude 58° 5′. Behind Takhli Island there is a good anchorage, well sheltered from all winds. The coal seams are on the main shore opposite the island and close to the entrance. The rocks are chiefly coarse sandstones, resting conformably on an andesitic agglomerate and containing andesitic pebbles. These sandstones have a thickness of 250 feet or more and dip about 30 NE. Low down in the series are strata of stream-bedded, sharp gravel, in layers about 5 feet thick, with three seams of impure coal, each about 18 inches thick. About 4 inches of this is pure, glossy coal, having a bituminous aspect Unlike most Alaskan coals, it soils the hands when touched, and is said to be good for use in a blacksmith's forge. These beds are broken off to the east by a granitic dike, weathering reddish, and were probably once covered by a more recent basalt which forms the mass of the adjacent hills. This basalt is irrupted into the sandstone, in some places inclosing blackened masses of sandstone. The sandstones show bits of carbonized vegetable matter and impressions of reeds, etc., recalling those found at Cape Douglas, but no identifiable plants.

An analysis of this coal affords the following results:

Analysis of coal from Amalik Harbor, Alaska.

	Per cent.
Moisture	1.62
Volatile matter not moisture	36.56
Coke	52.92
Ash	8.90

The ash is yellowish and the coke rather brilliant and coherent. The percentage of sulphur to the whole coal is 0.75. It is evident that this is a pretty good coal, and contains more fixed carbon and less moisture than any other Alaskan coal of which we have an analysis. The small dimensions of the seam, however, forbid anticipating any commercial future for it, though it may be useful for local purposes.

KATMAI.

Katmai Bay, some miles westward from Amalik Harbor, is the site of a village and trading station. The portage across the mountains of the peninsula ends here. On this portage both coal and petroleum have been found, the exact locality not being stated. The latter is a dark lubricating oil, which is said to float on the surface of certain ponds or lakes. No information could be obtained about the coal, but it almost certainly belongs to the age of the Kenai beds.[1]

[1] Tenth Census, Report on Alaska, p. 87.

KADIAK ISLANDS.

Tertiary beds occur in various places on the islands of the Kadiak group, both of Kenai age and of the later Unga beds containing Miocene marine fossils.

On the island of Kadiak marine Miocene strata are found, and among the specimens brought back by Wossnessenski were clay ironstones containing plant remains referable to the Kenai group. These stones were used by the native women for reddening the inner surface of dressed skins, and the only indication of locality for them is that they came from the northern part of the island. About the middle of the island, surrounding Ugak Bay, at the old settlement of Orlovsk, and on the northern shore of Miliuda Bay next southward, and on the opposite side of the island, part of the shores of Uganuk Bay and of Uganuk Island in the bay, sandstones with lignite in thin seams, overlain in places by marine sandstones like those of Unga, are reported on the authority of Kharitonoff and other Russians familiar with the island.

RED RIVER.

Coal exists in a clay bank near the beach at Red River, Kadiak, of which a specimen was obtained by Dr. Becker and Mr. Purington. An analysis affords the following data:

Analysis of coal from Red River, Alaska.

	Per cent.
Moisture	12.31
Volatile matter not moisture	51.48
Coke	33.80
Ash	2.41

The coke was sooty and noncoherent. The percentage of sulphur to the whole coal was 0.17.

SITKINAK ISLAND.

Several years ago a number of veins of coal were discovered on the high island of Sitkinak, in the southwest part of the Kadiak group. The mineral is said to possess good steam-making qualities, but to be inconveniently situated for access.[1]

YANTARNIE BAY.

On the south shore of the peninsula, in west longitude 157° 10′, is a small bay called Yantarnie, near which, in the lignite bearing beds, amber was found and traded by the natives of the peninsula with the Kadiak Eskimo.[2]

[1] Eleventh Census, Report on Alaska, 1893, p. 78.
[2] Bull. U. S. Geol. Survey No. 84, 1892, p. 239.

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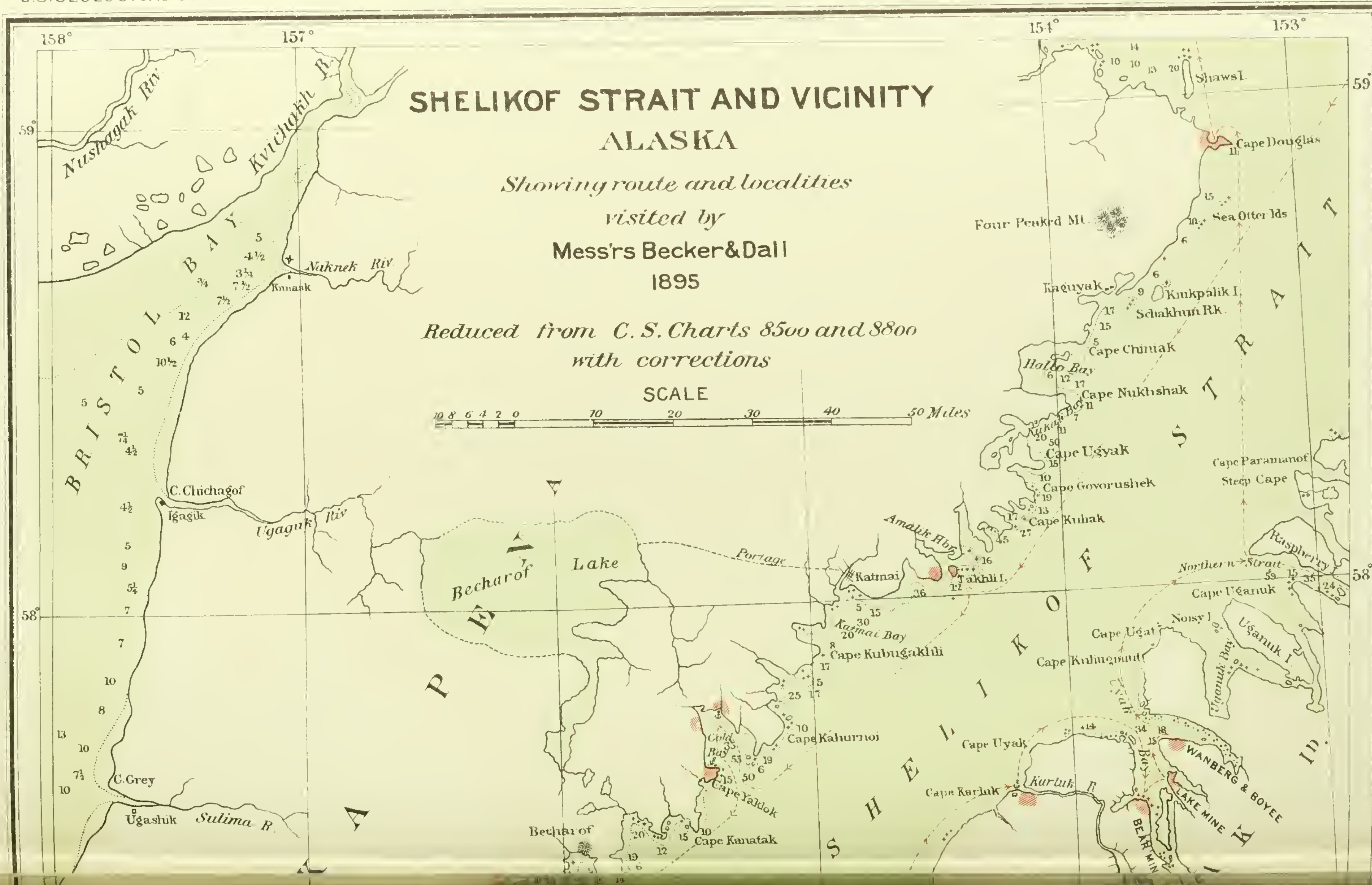
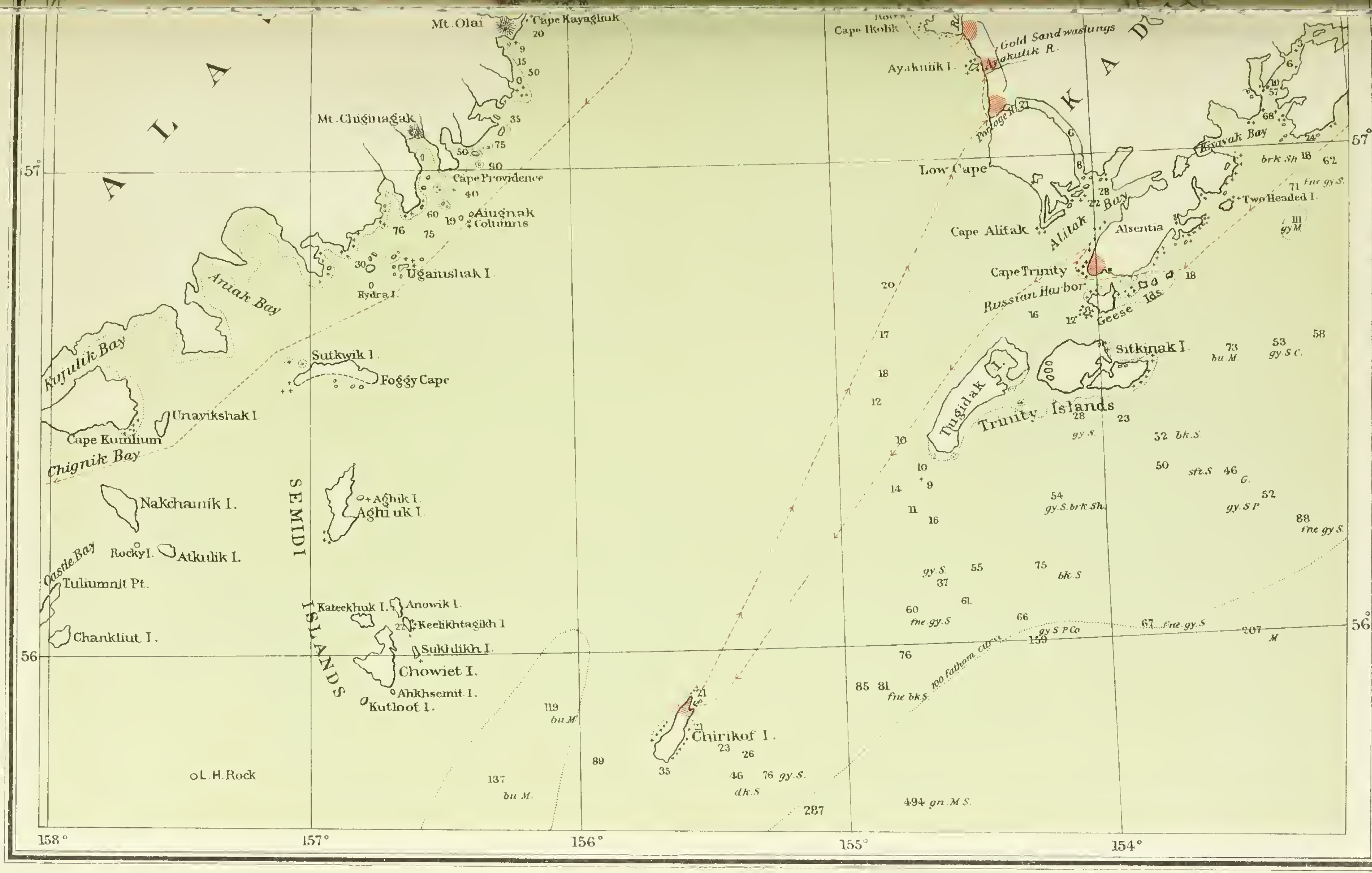

SHELIKOF STRAIT AND VICINITY
ALASKA
Showing route and localities
visited by
Mess'rs Becker & Dall
1895
Reduced from C. S. Charts 8500 and 8800
with corrections
SCALE
50 Miles
BRISTOL BAY
Nushagak Riv.
Kvichakh R.
Naknek Riv.
Kinaak
C. Chichagof
Igagik
Ugaguk Riv.
Becharof Lake
Portage
C. Grey
Ugashik
Sulima R.
Becharof
Katmai
Katmai Bay
Cape Kubugakhli
Cape Kahurnoi
Cold Bay
Cape Yaldok
Cape Kanatak
Amalik Hbr.
Takhli I.
Cape Kuliak
Cape Govorushek
Cape Ugyak
Cape Nukhshak
Hallo Bay
Cape Chiniak
Kaguyak
Kukpalik I.
Schakhun Rk.
Four Peaked Mt.
Sea Otter Ids
Cape Douglas
Shaws I.
Cape Paramanof
Steep Cape
Raspberry
Northern Strait
Cape Uganuk
Noisy I.
Uganuk I.
Uganuk Bay
Cape Ugat
Cape Kuliuginuut
Uyak Bay
Cape Uyak
Cape Karluk
Karluk R.
WANBERG & BOYEE
LAKE MINE
BEAR MIN
SHELIKOF STRAIT
KODIAK ID.
ALASKA PEN


A L A S K A
Mt. Olai
Cape Kayagliuk
Mt. Chuginagak
Cape Providence
Aiugnak Columns
Uganushak I.
Hydra I.
Aniak Bay
Kujulik Bay
Sutkwik I.
Foggy Cape
Unavikshak I.
Cape Kumlium
Chignik Bay
Nakchamik I.
SEMIDI ISLANDS
Aghik I.
Aghiuk I.
Rocky I.
Atkulik I.
Castle Bay
Tuliumnit Pt.
Chankliut I.
Kateekhuk I.
Anowik I.
Keelikhtagikh I.
Sukhlikh I.
Chowiet I.
Ahkhsemit I.
Kutloof I.
L. H. Rock
Chirikof I.
Cape Ikolik
Ayakulik I.
Gold Sand washings
Ayakulik R.
Low Cape
Cape Alitak
Alitak Bay
Alsentia
Cape Trinity
Russian Harbor
Geese Ids.
Sitkinak I.
Tugidak I.
Trinity Islands
Kaguyak Bay
Two Headed I.
100 fathom curve
57°
56°
158°
157°
156°
155°
154°
JULIUS BIEN & CO. N.Y.

COLD BAY.

Though no strata evidently of Kenai age were found in this bay, yet there were in several places fossil wood and vegetable remains. Near the northeast part of the harbor, east of a stream which comes in here, the rocks consist chiefly of calcareous sandstones, or sandy limestones, containing numerous concretionary nodules and some pebbles. In this nearly horizontal limestone, which is very massive and weathers into most bizarre shapes near the shore, we found a small seam of carbonaceous shale with occasional thin laminæ of clear coal. This shale is only a few inches thick. In shaly streaks of the limestone were vegetable impressions resembling those noted at Cape Douglas. On the other side of the stream, above the anchorage, these strata were arched and dipped 30° NW. On the opposite side of the main bay, well up on the hillside, was found a calcareous shale, with impressions of pine needles, above which was a heavy bed of conglomerate covered by a hard, perhaps andesitic, rock of igneous origin. From fragments fallen from above it seemed that this rock is more coarse-grained and friable higher up. It is unconformable with the other rocks. In the limestones near the south point of entrance impressions of reed-like plants and much fossil wood were observed. No coal seams were observed in this vicinity.

CHIGNIK BAY.

This is a large bay, much misrepresented on current charts, with several anchorages on the southwest shore, and at the southwestern extreme a large lagoon, into which a good-sized river flows, carrying the drainage from a series of large lakes. On this lagoon is a salmon cannery which puts up several million pounds of salmon during the season, and employs a stern-wheel steamer and several launches in its work, besides using a large amount of fuel to run the machinery of the works. Of late this fuel has been supplied from local coal seams situated on the river about a mile above the point where it enters the lagoon. We were fortunate enough to reach the cannery belonging to the Alaska Packers' Association on the last day of the season, thus having an opportunity of inspecting the works in operation, and of taking a trip to the coal mine on the steamer belonging to the works as she made her last trip of the season. She can make the trip only at certain stages of the tide, as at low water the upper part of the lagoon is nearly dry. The distance from the cannery is about 8 miles. Mr. William D. Smith, the superintendent, was most courteous, and we are under obligations to him for facilitating our work by every means in his power.

CHIGNIK RIVER.

After threading the very tortuous channel of the upper part of the lagoon, where the water hardly exceeded 3 feet in depth and the bottom in some places seemed fairly paved with flatfish, we entered the river, which was about 100 yards in width and runs between perpendicular low bluffs of Tertiary sandstone. The channel here varied from 4 to 6 feet in depth. A few miles from the sea there is a large lake 6 or 8 miles long, which connects by 5 or 6 miles of river with another lake, said to be as large as the first. In these lakes the salmon spawn.

About 1885 a coal seam was discovered by a man named Henderson, but he did not take steps to maintain his claim, and was followed in possession by Robert Lee, who did some exploration and worked at the mine during four years, taking out several hundred tons of coal. Lee sold his rights to the Alaska Packers' Association for $1,765 in 1892. In 1893 they proceeded to develop the mine after a crude fashion, using

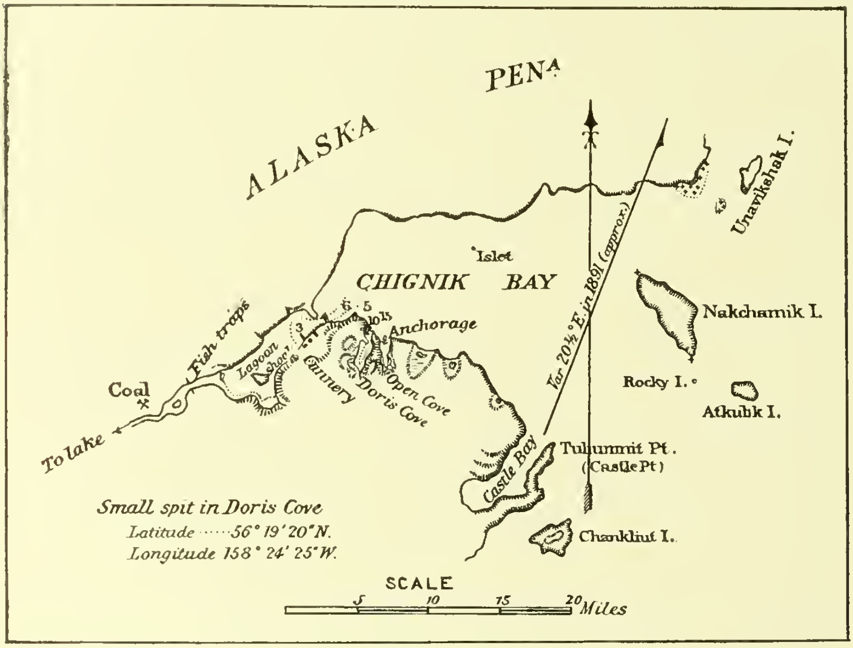


FIG. 24.—Sketch of Chignik Bay, showing location of coal mine; corrected from the charts by observations made in 1895 by W. H. Dall.

the coal for the canneries. During the summer three men are employed, who take out about 2½ tons of coal a day, at a cost of $3 a ton. About 350 tons a year, or 1,000 tons in all, have, so far, been mined here. During the winter two men are employed, and paid at the rate of 25 cents an hour, working as much or as little as they please. There is no machinery, and the work is done by blasting, the coal being run out in wheelbarrows. The mine is directly on the bluff, on the left bank of the stream. The beds dip N. 25° E. and the strike is N. 15° to 20° W. The bedding is very regular on the whole, with a few small slips. The coal occurs in one small seam, about 16 inches in average thickness, of which 1 inch is a more or less regular streak of sandstone. Above this seam are about 11 inches of hard sandstone and 6 inches of coal. About 6 feet higher is a 6 or 8 inch seam, very adhesive to the roof, which is of a very firm sandstone. The coal is solid, clean, bright, with no visible pyrite or lime. The rocks are of a brownish sandstone, gray where not weathered. There are few fossils, mostly stems or reeds, with an occasional leaf of a deciduous tree. One specimen of *Sequoia Langsdorfii* was obtained.

There are two 6-foot tunnels, about 40 feet apart and 240 feet long. The only timbering is in the form of uprights that have been put in to support the roof, which, though of exceptional strength, shows signs of weakness in spots. The upper tunnel has been robbed to a width of 40 feet in the clear in some places, with a single crosscut to the lower tunnel. We felt obliged to warn the workmen, who are old coal miners, that if supports were not speedily furnished a cave-in might be confidently expected during the coming winter.

The seam comes to the surface of the ground in a ravine about 30 feet above the upper tunnel, and has been traced inland more than half a mile.

Experiments in burning at the cannery, according to the engineer in charge, show that 118 pounds of Chignik equal 100 pounds of Wellington (B. C.) coal. It does not clinker nor soot the tubing. The ash is granular, and reddish-gray in color. The coal gives very little smoke, and is a satisfactory steaming coal.

An analysis of specimens of this coal, taken from the vein in place, affords the following data:

Analysis of coal from Chignik Bay, Alaska.

	Per cent.
Moisture	1.89
Volatile matter not moisture	41.47
Coke	48.46
Ash	8.18

The coke is brilliant and coherent. The percentage of sulphur in the whole coal is 1.71.

DORIS COVE.

On the south side of Chignik Bay, a little to the westward of the southwestern headland, is a small anchorage, surveyed by me in 1874, now known as Doris Cove, situated in about latitude 56° 20′ and west longitude 158° 24′. Here an outcrop of sandstone belonging to the Kenai group was observed, from which a number of fossil plants were collected. The bluffs here are about 500 feet high, consisting of a series of sandstone, slates, and conglomerates, with thin leaves of lignite, the whole nearly horizontal, and extending several miles toward Tuliumnit Point. From the specimens obtained six species of plants were identified by Lesquereux.[1]

COAST FROM CHIGNIK BAY TO PORTAGE BAY.

A short distance southwestward from Chignik Bay (west longitude 159°) the leaf and lignite beds crop out again on the south shore of the peninsula at Coal Cape. Southwest of this cape lies the small group of Chiachi Islands, surveyed by me in 1874. Here the bed rock is syenite, unconformably overlain in places by sandstones and conglomerates, the latter sometimes of waterworn material and sometimes of sharp gravel, with vegetable remains. The sandstones are often altered by outbreaks of reddish lava in large masses, and all the rocks at this locality appear much contorted and metamorphosed.

Still farther west (west longitude 160° 35′) the south coast of the peninsula is indented by Portage Bay, at the head of which a large stream comes in and a low divide affords a portage to Herendeen Bay, a branch of Port Möller, which indents the shore of the peninsula from Bering Sea on the north. West of Portage Bay other inlets enter from the south in the following order, namely, Beaver and Otter bays, Coal Bay, and Pavloff Bay, the latter connected by a very low divide with the head of Herendeen Bay, and thus indirectly with Port Möller. The vicinity in which these bays are found is of extreme geologic interest. From Port Möller several active volcanoes are in view, among the rugged flanks of which may be seen a number of glaciers. Hot springs flow into the bay from a small peninsula, on which are extensive shell heaps, indicating prehistoric occupation of the locality by a population of some magnitude. Near the head of the bay Mesozoic fossiliferous strata come down to the beach. On the east are Tertiary sandstones belonging probably to the Kenai group. Fragments of lignite and bituminous shale are not rare on the beach. At the head of Portage Bay, a few miles away, lignite beds are reported by Veniaminoff, and, as the name indicates, they also exist at Coal Bay. The Pavloff volcano is a high peak, emitting smoke and occasional flames, and is situated on the west side of Pavloff Bay. From the vicinity of the mountain Wossnessenski obtained "good stone coal," according to Grewingk (op. cit., p. 57), and this is also one of the localities reported to afford amber. When visited in 1874 by the Coast Survey parties, the shores of Port Möller were inhabited by large numbers of brown bear and reindeer, the rivers were alive with salmon, and hundreds of walrus sunned themselves on the sand-bars near the sea. It will be seen that for the naturalist and geologist it would be hard to find a place combining more interesting features.

Masses of amber of more than ordinary size have been obtained on

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[1] Proc. U. S. Nat. Mus. for 1882, pp. 443–449.

the beach at Portage Bay. I was informed by a gentleman who has been many years in this region that a few years ago, when searching the bay for salmon streams, he gathered several pounds of amber pebbles from the strand.

HERENDEEN BAY.

A deposit of coal from which great things were expected is situated on the peninsula which separates Herendeen Bay from Port Möller. An area of about 20 square miles was supposed to be underlain by coal, and a corporation under the name of the Alaska Mining and Development Company was organized in 1889 to develop it. According to Captain Hague, one of the stockholders, two tunnels were run in—one about 200 and the other about 300 feet—on a coal seam of 4 feet average thickness. The mine was situated a mile and a quarter inland from Mine Harbor, a cove of Herendeen Bay, where the miners had their cabins. The coal was brought to the water front by a steam motor on a small tramway. Several hundred tons were taken out in 1890, of which the U. S. S. *Albatross* used between 200 and 300 tons. The annexed report[1] by the engineer of the *Albatross* encouraged the

[1] The following report is extracted from the Bulletin of the United States Fish Commission, Vol. IX, for 1889, pp. 282-283, Washington, 1891:

UNITED STATES FISH COMMISSION STEAMER ALBATROSS,
Herendeen Bay, Alaska, July 24, 1890.

SIR: The following statement regarding the coal received from the mine recently opened in Herendeen Bay is based on the results obtained with some 80 tons of this coal consumed while this vessel was engaged in her usual work at sea under average conditions.

The quantities of coal consumed and of refuse matter were carefully measured; the behavior of the coal in the furnaces was closely observed, and the results obtained have been deduced from the entries in the steam log.

The average consumption of the coal was at the rate of 25 pounds per square foot of grate per hour. The boilers furnished the same amount of steam as when we have been using a fair quality of Wellington coal, but to obtain this result we had to burn from 20 to 25 per cent more of the Herendeen Bay coal.

The coal ignites readily and burns with considerable flame, forming a loosely cohering coke, which easily breaks up into small pieces; thus a considerable amount of small particles of coal is lost through the grates. There was a large proportion of fine stuff in the coal, which burnt well, but contained an excessive quantity of refuse matter.

The refuse amounted to 26 per cent of the total weight of fuel consumed; it consists of ash and cinders, no glassy clinker being formed. The smoke produced is lighter in color than that of Wellington coal, and less soot is formed.

To form a correct estimate of the value of this coal for steaming purposes from the foregoing statement, the following facts should be taken into consideration, viz, the coal received by us was the first lot taken from this newly opened mine; it came from one of the smaller veins through which a tunnel had been driven then 200 feet in order to get access to the main veins; no proper facilities for screening the coal existed, and in order to supply the quantity required by us a large amount of fine coal, containing much dirt, was delivered. It may be reasonably expected that, as the mine becomes further developed and proper screening facilities are provided, the amount of refuse matter in the coal will be greatly diminished, and its steam-generating power correspondingly increased.

It will be, however, absolutely necessary to store this coal under shelter, as it appears to absorb moisture readily, and the constant rains which have prevailed in this region during the present season would soon saturate it to such an extent as to greatly diminish its value as a fuel.

Respectfully,

C. R. ROELKER,
Passed Assistant Engineer, U. S. N.

Lieut. Commander Z. L. TANNER, U. S. N.,
Commanding United States Fish Commission Steamer Albatross.

owners of the property to such a degree that an engineer was employed to survey the property and lay out an experimental line for a proposed tramway to Portage Bay, on the Pacific shore of the peninsula, a distance of 12 miles or so from the mine. The map herewith is a reduced copy of this unpublished survey, for the use of which we are indebted to Capt. E. P. Herendeen. During the visit of the *Albatross* a number of fossil plants were collected and subsequently reported upon by Mr. F. H. Knowlton,[1] from whose introduction the following notes are extracted:

"Herendeen Bay, the locality affording the specimens that form the basis of this paper, is on the northern side of the Alaskan Peninsula and forms a branch of Port Möller (latitude 55° 40′, longitude 160° 40′ ±). The plants were collected July 28, 1890, by Mr. Charles H. Townsend, resident naturalist of the United States Fish Commission steamer *Albatross*. Mr. Townsend has furnished the following copy of his notes relating to their occurrence:

> *July 28, 1890.*—In making a tramway to the new coal mine just opened here (Herendeen Bay), one of the slaty cuttings exposed a large deposit of fossil leaves and ferns, about a mile from the beach, at the head of a little valley among the hills and within a few hundred yards of the mine itself. We visited the place twice and succeeded in getting a considerable quantity of specimens. Coal veins crop out in several places in the region of this bay. The first output of the new mine is now being used in the furnaces of the *Albatross*, but it is from near the surface and rather slaty.

"Mr. Townsend further adds:

> The country is mountainous and treeless, but covered with bushes and smaller vegetation. It is in general volcanic, and there are lofty peaks, one of which, Pavloff, has been seen smoking.

"The material in which the plants are preserved is a fine argillaceous sandstone, very well fitted for retaining the impressions. The vegetable remains are in most cases very numerous, even on small fragments of matrix."

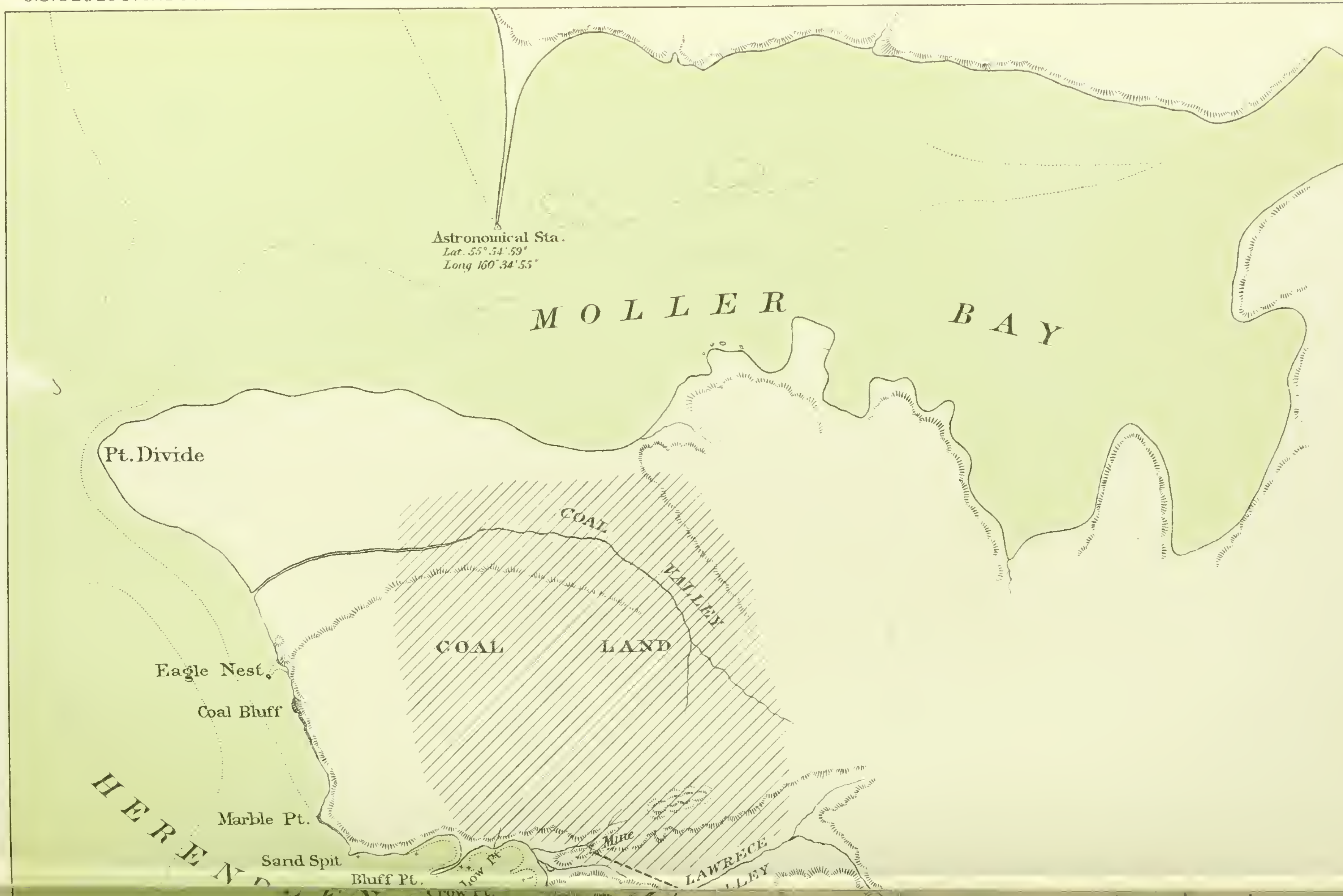
Fifteen species of plants were identified from this locality, which will be found enumerated in the appendix on Paleobotany.

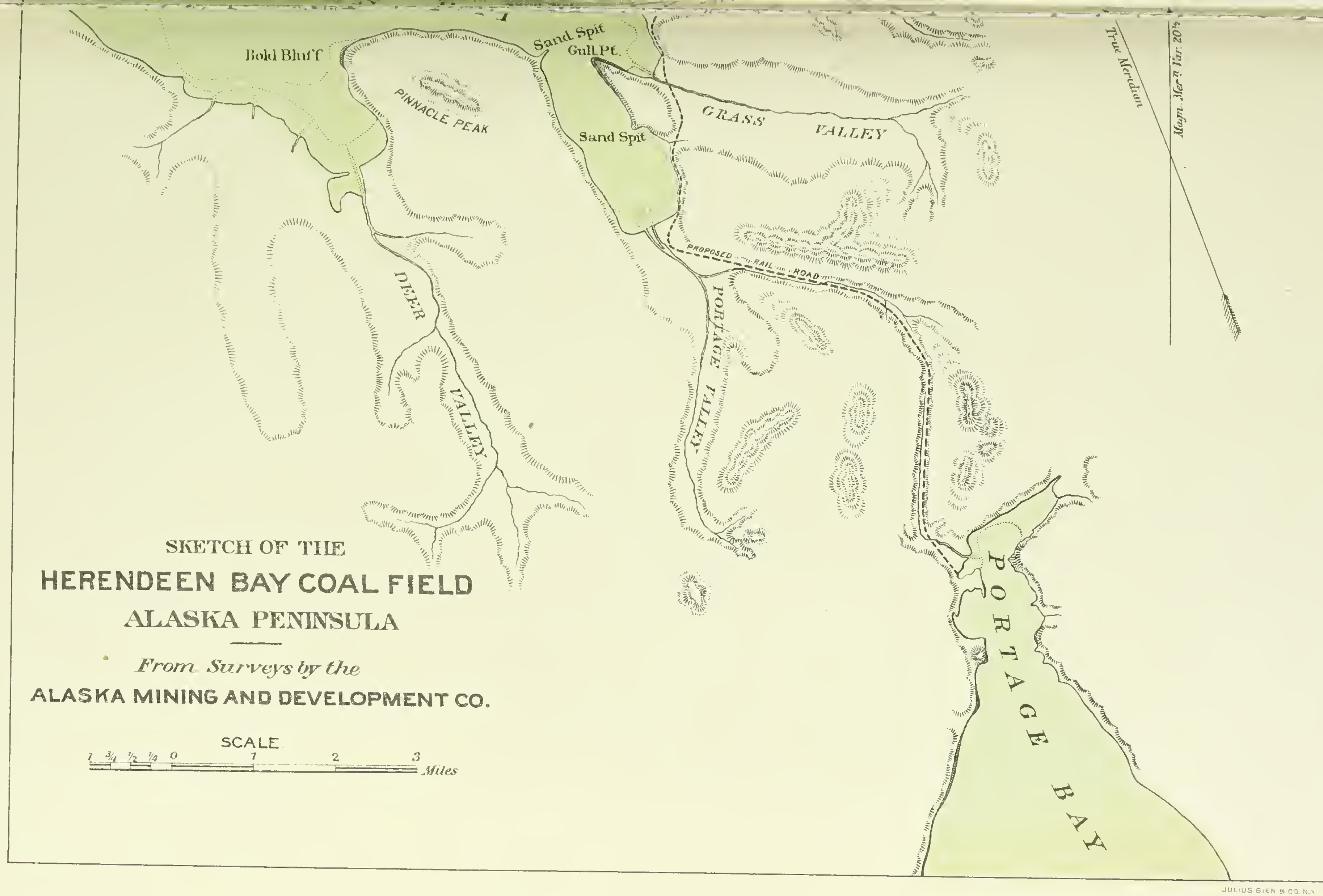
After pushing their tunnels to the distance stated, the vein was suddenly cut off by a fault in the strata, and all attempts to recover it proved fruitless. The presence of a more or less active volcano in the near vicinity rendered this result less surprising, as the Tertiary strata have been subjected to much disturbance by comparatively modern volcanic action along the line of this peninsula.

An attempt to visit the locality of the now abandoned workings at Herendeen Bay was frustrated by the urgency of public business connected with the patrol of Bering Sea, which required the services of all the cutters, on one of which we had expected to obtain transportation.

By the courtesy of Capt. G. Niebaum, of the Alaska Commercial

[1] Proc. U. S. Nat. Mus., Vol. XVII, No. 998, 1894, pp. 207-240.


Astronomical Sta.
Lat. 55° 54' 59"
Long 160° 34' 55"
MOLLER BAY
Pt. Divide
COAL VALLEY
COAL LAND
Eagle Nest
Coal Bluff
Marble Pt.
Sand Spit
Bluff Pt.
Low Pt.
Crow Pt.
Mine
LAWRECE


Bold Bluff
Sand Spit
Gull Pt.
Sand Spit
PINNACLE PEAK
GRASS VALLEY
PROPOSED RAIL ROAD
DEER VALLEY
PORTAGE VALLEY
PORTAGE BAY
True Meridian
Magn. Mer.n Var. 20¼
SKETCH OF THE
HERENDEEN BAY COAL FIELD
ALASKA PENINSULA
From Surveys by the
ALASKA MINING AND DEVELOPMENT CO.
SCALE
1 ¾ ½ ¼ 0 1 2 3
Miles
JULIUS BIEN & CO. N.Y.

Company, of San Francisco, a specimen of the coal from Herendeen Bay was secured, which afforded the following analysis:

Analysis of coal from Herendeen Bay, Alaska.

	Per cent.
Moisture	3.43
Volatile matter not moisture	39.00
Coke	47.40
Ash	10.17

The ash was of a pinkish color and free from clinker, the coke dull and slightly coherent. Percentage of sulphur in the whole coal, 0.44.

Unlike the workings of the other Alaskan mines of coal so far noted, this mine was subject to incursions of gas to such an extent as to require the use of safety lamps in working it, according to Captain Hagne.

SHUMAGIN ISLANDS.

UNGA AND POPOFF ISLANDS.

South of Portage Bay, across Unga Strait, lies the island of Unga, the principal island of the large Shumagin group, which extends some 50 miles to the south and east, and is noted for its cod and sea-otter fisheries. The eastern islands are granitic; those in the middle of the group are largely composed of metamorphic quartzites and schistose rocks. On the island of Unga and the adjacent Popoff Island, Tertiary beds are well exposed.

The principal exposure of the plant beds on the island of Unga is on the western shore of Zacharoff, Zachareffskaia, or Coal Bay, which indents the northern end of the island for about 3 miles. This locality was visited by me in 1865, and also in 1871, 1872, 1873, and 1895. The earlier observations of Wossnessenski and others are enumerated by Grewingk (op. cit., p. 97), but his details are very incomplete.

The following section was obtained by me in 1872:

	Feet.
1. Turf and soil	200 (Nos. 1–7)
2. Conglomerate of fine pebbles	
3. Conglomerate of larger bowlders	
4. Sandstone with marine fossils (1 foot)	
5. Thin friable sandy shales (6 inches)	
6. Conglomerate like No. 2	
7. Very coarse conglomerate (2 feet)	
8. Sandy shale with indistinct plant remains	$\frac{1}{3}$
9. Thin leaves of lignite aggregated into three series of 3 feet each, interstratified with beds of sand and gravel of variable thickness, with some pyrites and peroxide of iron, total about	40
10. Soft sandstone and gravel without large pebbles and little indurated	150
11. Another series similar to No. 9, but with none of the coal more than 8 inches in thickness, very pyritiferous	200
12. Clay ironstones with leaf impressions to the beach	4

The total height of the cliff is between 500 and 600 feet; two-thirds of it is precipitous, the rest more sloping; the crest is perhaps a third of a mile westward from the water's edge. The strata are somewhat waved in a north-and-south direction, and dip to the westward from 5° to 20°. Pl. LVI shows these cliffs as seen from across the bay.

Below ordinary low water another seam of coal is said to exist. The best veins of coal in the cliff are about a foot thick, hard, clear, and black except where weathered. It slacks up into small cubical fragments on exposure. There are three of these foot veins, separated by about 10 feet of sand and gravel. Over the middle vein is very friable blue shale, about 4 feet thick. Over the upper vein is a 4-inch layer of sandy shale containing many plant impressions, from which the collection submitted to Lesquereux was chiefly derived.

The coarser conglomerate (Nos. 3 and 7) contains some iron and weathers black on the face of the cliff. In a section published in a prospectus of a coal-mining company these black bands, which can be seen miles away on the face of the cliff, were indicated as coal veins; as in fact a distant observer would take them to be until otherwise informed.

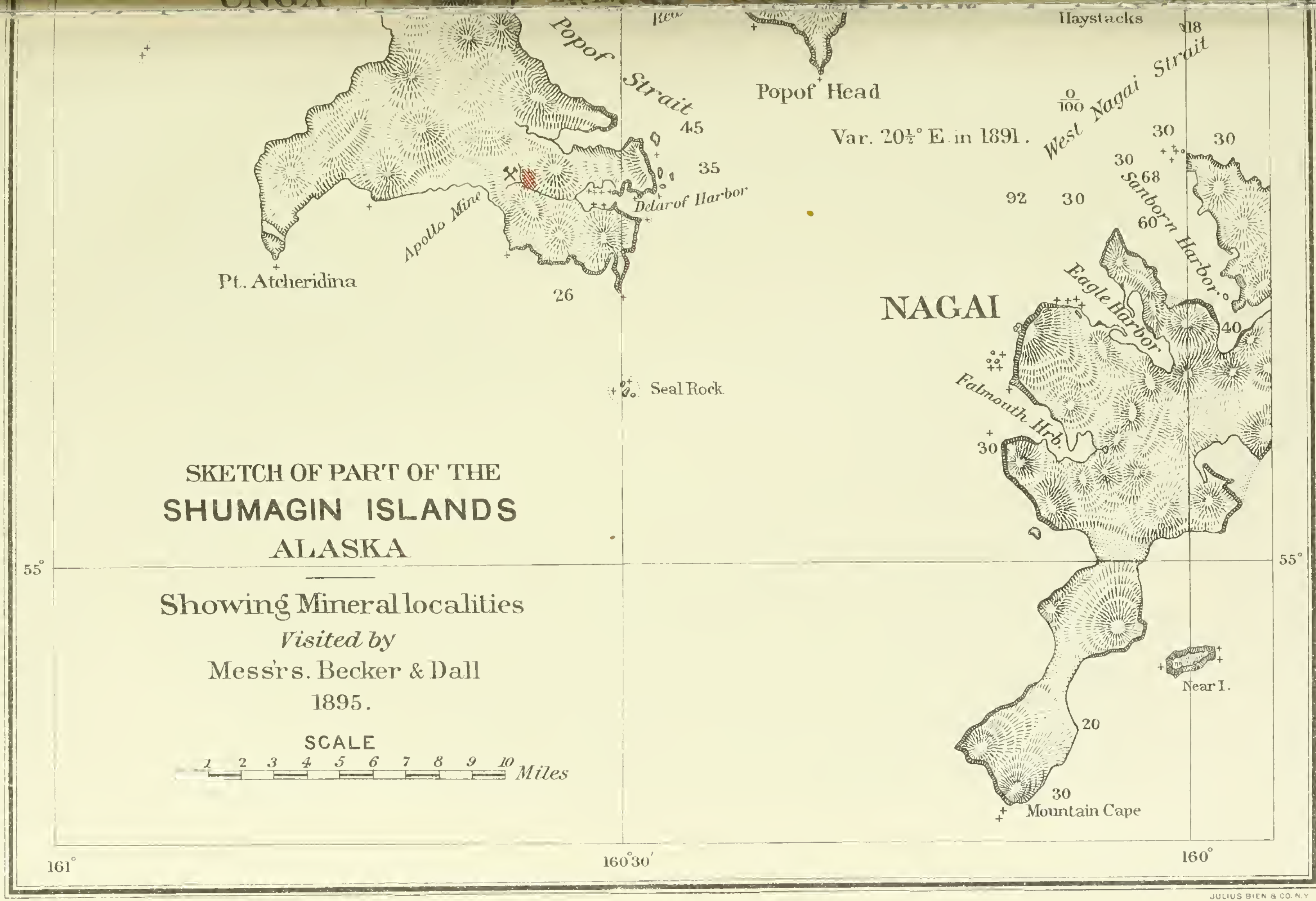
The species of plants collected at this locality were examined by Lesquereux, and proved to be identical with those from Cook Inlet; eight species were identified.

In the conglomerate (Nos. 6 and 7) many pieces of rolled silicified wood were found, some of which were bored by teredos. These beds are evidently a beach formation, presaging the depression which followed in which the marine bed above them was laid down. I have called them the Unga conglomerates; and the marine stratum, which will be referred to later, from the great abundance of *Crepidula prærupta* Conrad, I have called the Crepidula bed. It conformably overlies the others, and there can be no doubt of the continuity of the sedimentation through the whole series of lignitic and marine strata in this locality.

Fossil wood, referred to *Pinus pannonicus*, has been obtained at Delaroff Harbor, in the southern part of Unga, and some large pieces, collected on the beaches and forwarded to Dr. Newberry in 1873, were stated to be apparently cycadaceous. These may have been derived from adjacent Mesozoic strata. According to John Dix, a miner at the coal vein referred to, the mountains inland from the bay consist largely of similar sandstones.

The northeastern extremity of Unga Island and the northwestern part of Popoff Island are composed of sandstones and conglomerates similar to the upper part of the bluff in Zacharoff Bay, but they rise to only about 50 to 75 feet above the sea, and are broken and cut by dikes and larger intrusions of basaltic lava and diorite, and near the contacts are much altered and intersected by veins of chalcedonic quartz.


161'
160° 30'
160°
55° 30'
55° 30'
ALASKA
Portage Bay
Beaver Bay
Pt. Aliaksin
Pt. Swedania
STEPOVAK BAY
Guillemot I.
Bouldir I.
Scotland Rock (8 ft.)
Korovin
Henderson I.
High I.
Zachareffskaia B.
Gull I.
N.W. Head
Range I.
Sand Pt.
Coal
Var. 20¼° E. in 1891.
28
10
3
Gormans Strait
Andronica
POPOF
50


SKETCH OF PART OF THE
SHUMAGIN ISLANDS
ALASKA
Showing Mineral localities
Visited by
Mess'rs. Becker & Dall
1895.
SCALE
1 2 3 4 5 6 7 8 9 10 Miles
Popof Strait
Popof Head
Haystacks
West Nagai Strait
Var. 20½° E. in 1891.
Apollo Mine
Delarof Harbor
Pt. Atcheridina
Seal Rock
NAGAI
Eagle Harbor.
Sanborn Harbor.
Falmouth Hrb.
Near I.
Mountain Cape
55°
161°
160°30′
160°
JULIUS BIEN & CO. N.Y.

COAL HARBOR, SHUMAGINS.

On the western edge of Nagai similar rocks exist above the metamorphic schists and quartzites, but they are greatly altered and contorted and cover but a small area in comparison with underlying beds. It is probable that part of the island of Sannakh is composed of similar strata.

John Dix, above mentioned, worked at getting out coal from the Unga beds for some years. Messrs. Henry and Alexander Tibbey have since

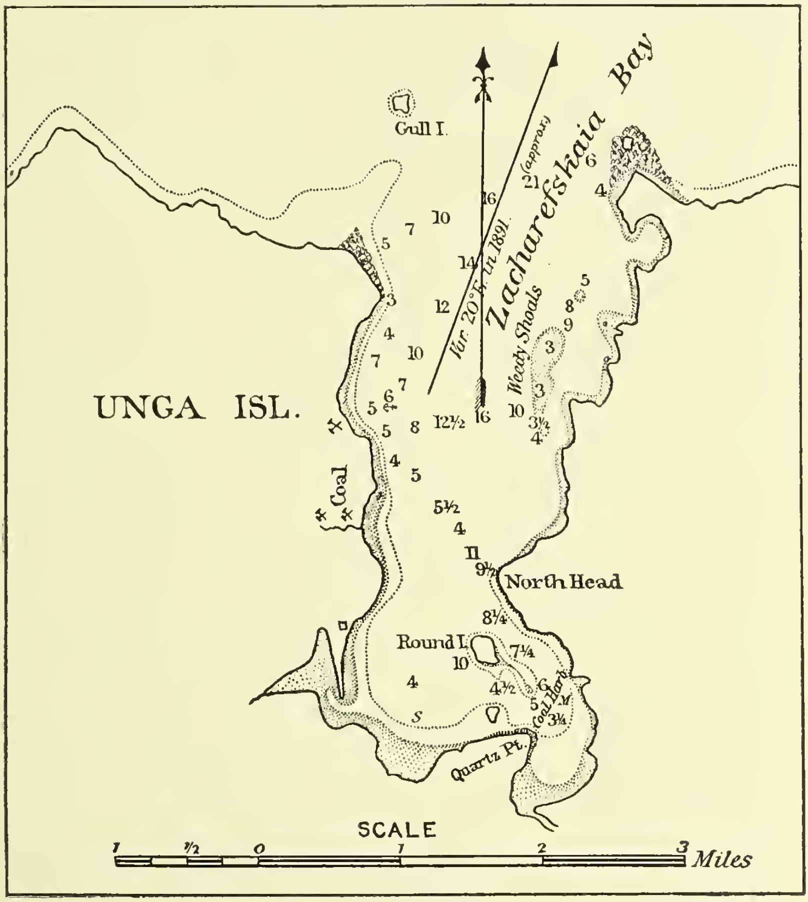


FIG. 25.—Sketch of Zachareffskaia Bay, Unga Island, Shumagins, showing location of lignite beds.

located on the bay, and have taken out small quantities of coal from time to time, which has been sold for local purposes. The water on the west side of the bay is shallow, and in going ashore with a small boat to examine the workings, August 8, 1895, we found hardly water enough half a mile from the beach to float the boat.

The Messrs. Tibbey have been interested in these mines for nine years and have been resident here for two years. Their workings were half a mile farther south than the point where the section given was taken, but the succession of the strata is essentially the same. Three tunnels had been made. That at the lower level had been pushed 150 feet, but being poorly timbered, had caved in. The next above, corresponding to No. 11 of the section, showed an 18-inch seam of dull coal fairly free from slate; above this were half a dozen small seams, 4 to 5 inches thick, of impure coal, partly brilliant and partly dull, the fissures much reddened by iron oxide and with many thin, sandy or shaly laminæ. In spots iron pyrites is very abundant. These seams are separated by wider bands of carbonaceous aluminous shale or gray, sandy layers. See Pl. LVII for view of this tunnel.

The tunnel from which this coal was obtained is about 6 feet high by 8 or 10 wide, and has been driven in about 20 feet. It seemed about 200 feet above the bay. About 100 feet higher is a third tunnel, of about the same size, partly timbered, with much percolating water. The coal here, probably corresponding to No. 9 of the section, is in very numerous small seams, varying from one-fourth of an inch to 2 inches in thickness, with bands of carbonaceous shale intermixed. The whole is of such poor quality as to be of little importance, so that this tunnel has not been worked of late.

At the Apollo mine, at Delaroff Harbor, in the southern part of the island, it was stated that a test of this coal had been made with unsatisfactory results, on account of the excess of sulphur and ash contained in the lignite. This confirms conclusions announced by the writer after an examination of the Unga coal deposits more than thirty years ago.

Specimens of the bright-colored and of the dull-colored lignites from the main seam were obtained, of which the following analyses have been made:

Analyses of coal from Unga Island, Alaska.

	Upper, bright.	Lower, dull.
	Per cent.	*Per cent.*
Moisture	11.26	10.58
Volatile matter not moisture	40.51	66.21
Coke	41.24	15.26
Ash	6.99	7.95
Sulphur	2.17	0.56

The ash in the upper bed is drab; in the lower, yellowish. The coke from both is dull and noncoherent. Much of the coal has a larger proportion of sulphur than that above mentioned, as the pyrite is very irregularly distributed.

At one time a company was formed to work the beds at Unga, under the title of the Alaska Coal Company. This was an earlier and a different company from that formed under the same name with interests

ENTRANCE OF TUNNEL, TIBBEY MINE, COAL HARBOR, SHUMAGINS.

in the mines at Kachemak Bay, Cook Inlet. According to the prospectus, the present company was organized September 21, 1871, under the laws of the State of California. The capital stock was $5,000,000. The president was W. A. Aldrich; the vice-president, W. H. Taylor; the treasurer, W. H. Sears; and the secretary, James T. Hoyt. The offices of the company were at room 63, Merchants' Exchange, California street, San Francisco, Cal.[1]

There are several reports by perfectly reliable persons in San Francisco on tests made with this coal, printed in the above prospectus, which can only be accounted for on the supposition that coal from some other locality in some way became mixed with the supposed Unga coal which was tested.

In March, 1872, with a party, the writer dug out about 14 tons of this coal for use in stove and galley on the U. S. S. *Humboldt*. Coal was needed badly, but the opinion was unanimous that this coal was extremely objectionable from the very large amount of sulphur, which gave out offensive fumes while burning, and the extraordinary quantity of ashes. The coal burned very rapidly, and was certainly not more than one-fourth as efficient as Seattle coal, which we had previously used. As in other Alaskan coals, there was practically no clinker and very little smoke. It is of course possible that in other parts of the seam the quality may be better, but on the whole our opinion of the Unga coal is unfavorable.

LOCALITIES IN THE ALEUTIAN ISLANDS.

In the chain of islands extending westward from the peninsula there are many which are more or less volcanic, but the chain is older than the volcanoes and volcanic islands it contains, and many of the islands are composed of sedimentary or metamorphic rocks. The chain doubtless marks a very ancient line of weakness or faulting in the earth's crust; and nearly all of the volcanoes are relatively very modern developments, due to geological changes which have been in progressive operation since early Mesozoic time.

AKUN.

Proceeding westward, the first island upon which lignitic beds are reported is Akun, where Postels[2] states he was told that coal exists.

UNALASKA.

The northern part of the island of Unalaska is better known than the rest. The principal harbor, Captains Bay, is surrounded with massive beds of andesitic rock and some basaltic lava; but several

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[1] Prospectus of the Alaska Coal Company (etc.), San Francisco. Women's Coop. Printing Co., 1871, 8°, 18 pp., 2 l. unp.; cut.

[2] Voy. Séniavine, 1836, vol. 3, p. 21.

localities in the interior of the island, according to tradition, afforded amber, and consequently should possess lignitic deposits. In the autumn of 1871 I endeavored, with a small party and an Aleut guide, to discover one of these so-called amber beds. The expedition reached the main ridge of the island some miles south from Captains Bay, and found the rocks to consist almost exclusively of syenite in mountain masses, overlain in some places by thin beds of clay and sand, apparently the result of decomposition of the syenite itself. The amber lake of Aleut tradition is a small body of water connected with two others. Above the lake rose a precipitous crag of conglomerate, 2,000 feet in height by estimation, the horizontal layers very distinctly bedded, graduating toward the top into hard, altered sandstone, very black and flinty. No fossils could be found in it, but the weather became so inclement as to render it necessary to return without making an exhaustive search, and these beds may eventually prove to belong to the leaf-bearing series. The Aleuts declare that the disintegrated sandstone in former times afforded occasional bits of amber, which were obtained from the gravel around the edge of the lake.

Another locality for amber, and inferentially for lignitic strata, is reported by Veniaminoff, from statements by the Aleuts, to exist in the western part of the island, in the mountains near the head of Makrofski Bay. Here there is said to be a lake containing an island of friable sandstone and unconsolidated gravel out of which the Aleuts formerly obtained small pieces of amber.

Marine Miocene beds exist on Makushin Bay, near the north-northwest base of the volcano of the same name, but no leaf beds are reported at this place. On the eastern shore of Port Levasheff, Wossnessenski obtained small fragments of lignite, which he supposed to have been brought down by streams from lignite beds in the interior of the islands, the adjacent rocks being clay-porphyry.

Slate Point, 2½ miles eastward from the entrance to Chernoffski Harbor, is composed of a black stratified material, perhaps belonging to this series, but which has not been closely scrutinized.

UMNAK.

On the northwestern end of the island of Umnak, the next westward in the chain, near Tulikskoi Volcano, is a lake overhung by a cliff of unconsolidated beds. The Aleuts were in the habit of stretching a seal hide between two kayaks and dislodging this earthy material, which would fall upon the hide, and was carefully washed for amber. Near Cape Yegorkoffski, Eschscholtz and Chamisso collected fossil dicotyledonous wood from the bed of a lake which had been drained by changes due to an earthquake.

ATKA.

Westward from Umnak many of the smaller islands are volcanic, and but little is known of any of them until the island of Atka is reached

(174° west longitude). On the western side of the north part of this island it is indented by Korovinski Bay, from which several small arms extend southward and northward. The north shores are composed chiefly of nearly horizontal layers of volcanic breccia dipping slightly to the northeast and rising to 1,000 feet, interstratified with beds of ashes, cinders, and solfataric clays, in some of which marine Miocene fossil shells occur. On the south shore, especially on the east shore of Sandy Bay, are found pieces of fossil wood of a gray color, which burn slowly, and other pieces which are silicified. They appear to lie under the soil, between the latter and a conglomerate resembling that of Unga, composed chiefly of rounded porphyritic pebbles, capped on the eastern portion with partly columnar basalt.

Nazan Bay, on the east side of the island, opposite Korovinski Bay, and separated from it by a low isthmus, exhibits highly altered beds of conglomerate and volcanic breccia, nearly horizontal and dipping slightly to the northwest. A more compact, flinty, greenish metamorphic rock, with a similar dip but more contorted and much intersected by dikes of basalt, is the material of which the south shore and the islets protecting the anchorage are composed.

ADAKH.

On the west side of the island of Adakh is a harbor called the Bay of Islands, the northern shores of which are composed of coarse sandstones like those of the Kenai group, dipping in general to the northeast. They are greatly altered by basaltic and frothy lavas, which have burned the sandstones overlain by them to a red color. No fossils were found in them when examined by me in 1873.

AMCHITKA.

The island of Amchitka is notably low and level compared with most of the Aleutians. At Constantine Harbor, on the northeastern shore, the rocks forming its eastern coast are crystalline and probably volcanic. The west side of the harbor appears to be composed of low bluffs, not exceeding 60 feet high, of a much altered conglomerate. Westward about a mile is Kiriloff Bay, a small, rocky indentation, formerly the site of a village (1849), but now deserted. Here the conglomerate and sandstones are less altered, and specimens of lignite and fossil wood were collected by Wossnessenski. Still farther west small veins of lignitic coal with plant remains are reported by Shayeshnikoff.

KISKA.

The island of Kiska has a fine harbor (west longitude 182° 30′), which is protected on the east by the island of Little Kiska. The shore belonging to the main island borders on the water in many places as steep bluffs to 200 feet high, composed of a coarse conglomerate, of which the upper layers merge into a breccia of volcanic material, but obviously arranged in water. These are broken through by eruptive clay-porphyries of a greenish color, rising to 150 feet, and capped over all by a basaltic or coarsely crystalline syenitic rock, in some places 300 feet thick. On the bluff of Little Kiska, facing the harbor, the porphyrite appears toward the southwest unconformably over them, and dipping northward are sandstones resembling those of the Kenai series, but in which, in 1873, no fossils were found. Covering those, and extending to the northwest point of Little Kiska, is a magnificent cliff of the crystalline eruptive rock before referred to, which here forms enormous prisms, five-sided, from a foot to 20 inches in diameter, standing vertically in the cliff like organ pipes, and sometimes continuous as a single prism to the length of more than 50 feet.

ATTU.

The westernmost of the Aleutian chain is the island of Attu, which is destitute of modern volcanic rocks. The harbor of Chichagoff, at the northeastern end of the island, is surrounded chiefly by metamorphic slates and quartzites, diorite, serpentine, and clay-porphyry, probably Mesozoic, and much contorted. It was reported by the natives that fossil wood was occasionally found on the beaches toward the western part of the island, but no Tertiary rocks or sandstones were observed by our party in 1873.

LOCALITIES IN NORTHERN ALASKA.

NUNIVAK ISLAND.

Northward from the Alaskan Peninsula little is known of the geology until the island of Nunivak is reached. At the northeastern extremity of this island is an anchorage surveyed by me in 1874. Here the shores, though abrupt, are low, and composed of much-altered sandstones, nearly horizontal and more or less overlain by recent basaltic lavas. In the interior small volcanic cones, or hills resembling volcanic cones, were observed and supposed to be the source of these lavas. From their appearance and their relation to the lavas it is probable that these sandstones belong to the Kenai group.

On a subsequent visit to this locality, Etolin Harbor, Dr. George M. Dawson described the shores as bordered by horizontally bedded olivine-diabase of a very porous and cellular character. It is possible that during the work of surveying, which occupied nearly all my time while at Etolin Harbor, I was misled by the appearance of these volcanic beds, as there was very little leisure and the weather was stormy, but I remember that one or two bits of fossil wood were seen in the rock I took for a sandstone, and which tended to confirm the impression that I had before me an altered member of the Kenai group. However, if this does not occur here, we owe to Dr. Dawson the discovery of a new locality where Kenai sandstones are covered by recent basalts, just across the strait from Etolin Harbor.

POINT VANCOUVER.

The northern shore of this point is stated by Dr. Dawson[1] to form scarped bluffs or cliffs rising from the edge of the sea, and presenting fine exposures of sandstone and sandy shales, well bedded, and dipping southward at low and undulating angles. At the extremity of the cape these beds appeared to be horizontal, and on the south side seemed to lie at higher and more irregular angles. These sandstones are gray, bluish, and brownish in color, rather soft, and sometimes nodular. They contain a very few dirty seams of coal or lignite, of which the thickest seen measured only a few inches. There are also in the sandstones numerous carbonaceous fragments and occasional fossil leaves, among which *Juglans acuminata* Heer was identified by Sir William Dawson.

Upon the beach at Vancouver fragments of vesicular basalt were observed by Dr. Dawson, and he was led to suppose that the stratified rocks are capped by basaltic flows in the higher hills a short distance inland from the extremity of the cape. The latter is a bold promontory, which probably rises to a height of 1,000 or 1,500 feet above the sea.

THE YUKON TERRITORY.

In the Yukon Valley, and thence to the shores of Norton Sound, a large area is occupied by lignite and leaf-bearing sandstones of the Kenai group, a smaller portion of which are overlain by the Nulato marine sandstones, analogous to the Crepidula bed of Unga in age, but containing a different series of fossil shells.

COAST OF NORTON SOUND.

On the seacoast between Unalaklik and Tolstoi Point these strata are exposed, much contorted, and dip generally at high angles. At Tolstoi Point they are met by the later basalts which southward form the shores of the sound, St. Michael and Stephens islands, and adjacent islets. In October, 1867, these exposures were examined by me, and from notes and sections made at the time the following description is condensed.

Southward from the mouth of the Unalaklik River, along the seashore for 6 miles, stretches a low, level plain of sand, soil, and turf, horizontal and from 5 to 20 feet thick. Then the alluvial layer rises, and below it is visible bluish or yellowish clay, soft, but distinctly bedded and dipping north by east 28° to 45°. It is 30 to 40 feet thick, covered by about 3 feet of soil. The lower layers of the clay contain fragments of silicified wood and lignite, sometimes preserving the original form of the trunk, but commonly broken. This continues a quarter of a mile to a small creek (No. 1), on the farther side of which

[1] Bull. Geol. Soc. Am., Vol. V, 1894, pp. 134–135.

appear beds of indurated sandstone, overlain by the clay and soil and underlain by a blackish shale, the succession being as follows:

	Feet.
1. Soil and clay, the latter sometimes absent	3
2. Greenish sandstone, dipping N. 35° to 40°	25
3. Blackish sandstone, dipping N. 35° to 40°	20
4. Shale, dipping 30° easterly	10

This series continues about 3 miles to Creek No. 2, along the shore, but the shale comes up so as to be exposed for only about 200 yards.

From Creek No. 2, along the shore for half a mile, we find blackish sandstone, with seams of shale 20 feet thick dipping SE. 80°, covered with clay and soil. This is succeeded by a gray sandstone 30 to 40 feet thick, with a dip of 45° NE. for nearly a mile, followed by 200 yards of the black sandstone, 40 feet thick, dipping SE. 65°. Then a turrited bluff of gray sandstone, vertical, 50 feet high, with seams of quartz and layers of shale and fragments of carbonized vegetable matter. Under this the black sandstone shows again on a level with the beach, both dipping NW. 85° for half a mile. The clay and two kinds of sandstone continue to crop out, with occasional layers of dark-colored shale and slaty rock dipping from north by east round to SE. 30° to 85°, to Tolstoi Point, the last 2 miles being formed of clear gray sandstone in bluffs 30 to 70 feet high, dipping NW. 70° to 80°, until the lava is reached at the point.

TOPAŃIKA.

Creek No. 2 is locally known as Topanika, and at its mouth is a camping place where the natives go to catch fish.

Following Topanika Creek easterly into the hills the greenish and blackish sands dip more and more steeply to the east, interleaved with shaly layers containing leaves and vegetable remains, among which leaves of *Platanus nobilis* Newberry, a foot across, were collected in a fine state of preservation.

Farther inland the same rocks become vertical and then dip toward the west, the beds resembling the radiating ribs of a fan. About 2,000 feet of these beds are continuously exposed without faulting, with the same fossils at intervals all the way. These beds extend inland between the sea and the Yukon River, where they appear again.

ULUKAK RIVER.

Starting from Unalaklik up the river of the same name, a branch called the Ulukak, about 2 miles above the Indian village of Iktigalik, affords a fine exposure of these rocks, as follows, beginning at the base:

	Feet.
1. Argillaceous, unfossiliferous, slaty rock, the layers of which become progressively harder downward	220
2. Shale, with some lignite, showing black	2
3. Argillaceous shale, with leaves of Platanus	15
4. The same, without fossils	15
5. White sandstone (probably marine)	20
6. Sand and soil to surface	10

The whole series dips conformably NNW. 25° to 55°.

This is the only locality on the river between Unalaklik and the village of Ulukak (some 30 miles in a direct line, but 60 by the river) where fossils were observed. The rocks, as on the coast, were more or less folded, and the dip is irregular.

LOWER YUKON VALLEY.

The Yukon Valley affords numerous exposures of the same group of sandstone along the right bank of the river. The first locality noted in ascending the river is just below Andreieffski fort, an old Russian trading post. High bluffs of black sandstone come down to the river just above the fort and continue for 10 miles, and just below the fort is the last small exposure, where a seam of bituminous shale about 6 inches thick was observed by me in 1868. This had been worked a little for fuel by the Russians, but abandoned, as the material was too impure to burn well. It dips in a westerly direction. Ascending the river, the sandstones are next observed along a stretch of about a mile near the native village called by the Russians "Starry Kwikhpak." Two miles and a half below Ikogmiut mission the sandstones along a strip of 3 or 4 miles alternate with older metamorphic and later trachytic rocks. Some layers of the sandstones here weather of a whitish color, dipping in a northwest direction with more or less folding and alteration by the action of the eruptives. Similar exposures appear near Koserski village; and at Lofka's, which is nearly in the same latitude as Tolstoi Point, Norton Sound (previously described), the sandstones begin to form the main mass of the strata exposed along the river, though the quartzites appear here and there. The sandstones in general dip toward the northwest at angles varying from 20° to 45°. A short distance below Kaltag a small seam of lignite occurs.

UPPER YUKON AND NULATO.

Above Kaltag the bluish sandstones of the Kenai group are overlain by brownish marine sandstones, which are best exposed just above Nulato, and hence have been named by me the Nulato sandstones.[1] They occur in successive waves or folds, extending in a northwest-and-southeast direction and cut nearly at right angles by the river. At some points eruptive rocks have forced their way through, tilting the sedimentary rocks nearly vertical and altering them near the contact with the eruptives. The blue sandstones occasionally appear above the level of the water.

About 7 miles below Nulato, on the south side of a level space or flat, a small bluff appears, at the extreme end of which the sandstones are nearly vertical. Here, between two contorted layers of shaly rock, a

[1] Bull. U. S. Geol. Survey No. 84, 1892, pp. 246, 331. Also Am. Jour. Sci., 3d series, Vol. XXIV, pp. 6, 7, 8, July, 1882.

small coal seam was examined in December, 1866. It has been squeezed out above and below, forming a mere pocket about 2 feet thick and not over 20 feet long on the exposed face. The shales contained obscure vegetable remains, but were much altered, probably by the heat evolved at the time they were folded. The average dip is N. 45°. The coal is good, but there are apparently only a few tons of it. The shales are conformable with the brown sandstone, which, however, is a marine formation, in which this deposit of lignite is a very exceptional incident.

Nulato marine sandstones.—Above Nulato appears to be exposed the highest of these sandstones, which there form bluffs 60 to 100 feet high, and farther up the river reach to 200 feet. In May, 1866, I obtained from the upper part of these beds Modiola, Tellina, Mytilus, Gastrochæna, and Mya, with worm tracks and obscure vegetable remains. The general appearance indicated a littoral formation.[1] These sandstones extend along the river from Kaltag to the Koyukuk Mountain and westward to the Kuthlatno and Ulukak rivers and the eastern base of the Shaktolik Hills, forming a sort of patch, approximately 90 miles northeast and southwest and not more than 30 miles wide, lying on a much larger area of Kenai sandstones. The latter form the mass of the hills between the Kutelno and Kuthlatno rivers and of the Shaktolik Hills. They extend on the Yukon above the Koyukuk Mountain, which is apparently of intrusive crystalline rock, eastward on the north bank to the Melozikakat River. Above Nulato they first appear about 5 miles above the bluff just mentioned as affording marine fossils, and there conformably underlie the marine sandstones and are themselves underlain by a hard black slate.

Near Melozikakat the bluffs appear also on the left bank, which is rarely the case on the Yukon below the Ramparts. Russell[2] has also noted the leaf beds 15 or 20 miles below the mouth of the Melozikakat, on the right bank of the Yukon, in connection with an interesting series of faults which they exhibit.

Ozocerite (?).—In connection with this lignite-bearing series a note on another carbonaceous deposit may be in place. The party commanded by Lieutentant Stoney, United States Navy, while exploring in the vicinity of the headwaters of the Colville, the Noatak, and Kowak rivers, north of the Yukon, were obliged to traverse large areas of barren, treeless tundra, and here they found on the surface rather abundantly scattered masses of a brown material resembling powerfully compressed peat, recalling pitch in hardness and weight, but not brilliant nor disposed to melt with heat, but making a clean cut, like "plug" tobacco, when whittled with a knife. This material was sufficiently inflammable to ignite and burn with a steady flame on applying a match to a corner of it, so that in their cold and weary journey it formed a most welcome

[1] Cf. Dall, in Am. Jour. Sci., 2d series, Vol. XLV, 1868, pp. 97-98.
[2] Bull. Geol. Soc. Am., Vol. I, 1890, p. 108.

substitute for wood or other fuel for the camp fire. The geological relations of this substance are unknown; it presented no traces of organic structure under an ordinary magnifier, but its nature and geographic location suggest that it may be connected with the lignite-bearing beds to the south of it, which we have just described.

KOWAK RIVER LIGNITES.

About 75 miles above the mouth of the Kowak River, which empties into Kotzebue Sound through Hotham Inlet, extensive deposits of lignite, associated with sandstone, shale, and conglomerate, were discovered by Lieut. J. C. Cantwell, United States Revenue Marine, and party, while exploring under direction of the Treasury Department in 1884. The coal belt on this river is about 30 miles wide, and passes through a series of high and partly timbered hills. It is often exposed along the river bank, and is frequently associated, as at Kenai, with beds of clay. It is soft, friable, and jet black in color. These beds lie directly in the trend northwesterly from the main body of beds of the Kenai group north of the Yukon, and there can be little, if any, doubt that they belong to the same series. The opinions which would connect them with the beds of coal on the Arctic coast, near Cape Lisburne, are, of course, erroneous. It has been determined by the observations of the *Corwin* party,[1] in 1885, that the coal beds of the Kowak do not extend to the valley of the Noatak, and can not, therefore, be continuous with those at Cape Lisburne.

CAPE BEAUFORT COAL MEASURES.

In regard to these last, it may be noted in passing that Silurian fossils, brachiopods, corals, and crinoids have been collected by Buckland, Fischer, Kupreanoff, and myself at Cape Lisburne and the adjacent Cape Thompson. A few miles farther up the coast, coal is found about a quarter of a mile away from the beach at Cape Beaufort. This coal is of a very different quality from the lignites of the southern part of Alaska, and from the presence of corals, apparently referable to the epoch of the Carboniferous period, which were collected from the débris of the rocks adjacent, it has been assumed to be of that age. Similar coal crops out below low-water mark in many places northward to Point Belcher, and is pushed up on the beaches by the grounded ice floes so that in some places nearly the whole of the beach gravel is made up of small fragments of coal. From this region Lesquereux[2] has described *Iritis alaskana*, collected at Cape Lisburne by Henry D. Woolfe, and Newberry[3] enumerates from the same locality and collector ten species

[1] Cruise of the *Corwin* in 1885, House Ex. Doc. No. 153, 49th Congress, 1st session, Washington, 1884; see p. 76.

[2] Proc. U. S. Nat. Mus. 1887, Vol. X, p. 36.

[3] Proc. U. S. Nat. Mus. 1888, Vol. XI, pp. 31–33.

which he regards as Neocomian, and which Professor Ward,[1] enumerating publications on Alaskan paleobotany, considers to indicate a Lower Cretaceous or possibly Upper Jurassic age. It seems tolerably certain that strata covering a considerable range on the geologic column, beginning with the Silurian, are represented in the vicinity of Cape Lisburne, and that the coal-bearing strata may be Mesozoic rather than Paleozoic.

The following notes are condensed from those which were contributed to the Eleventh Census report on Alaska by Mr. Henry D. Woolfe:

> Along the beach and coast line from Cape Lisburne for at least 40 miles an extensive and well-defined coal field exists. I was engaged for two seasons in exploiting these deposits. Research developed the existence of a body of coal extending over an area of 25 square miles. There are along the coast line for the distance mentioned numerous veins of coal from which the whalemen obtain supplies of fuel. The coal is of the type of semibituminous lignite. It makes steam quickly, but there is a very large percentage of ash and clinker, and its constant use causes an early burning out of furnace bars. * * * At present the whalemen dig out their supplies from the surface veins, climbing the cliffs to obtain it. * * * With any wind, except from the east or southeast, there is no protection on the coast mentioned, and the work of boating the coal off to a vessel lying at some distance from the shore is difficult and in windy weather dangerous. With the ice pack offshore a lee is obtained which makes smooth water and facilitates coaling. The limit of the important coal-bearing area to the north is at Cape Beaufort, though small seams are seen farther on. Between the seams bands of clear ice intervene, and I have noticed on the shelving banks of a small creek that runs through the coal land an oily exudation resembling petroleum.[2]

Mr. Woolfe's geology is a little peculiar, but since he has had more personal experience than anyone else with these deposits it was thought best to refer to his opinions.

WAINWRIGHT INLET.

There is a river, sometimes called the Koo or Koog (which simply means river), which falls into Wainwright Inlet. On the banks of this stream, in 1889, Mr. Woolfe found coal of a better quality than that at Cape Beaufort. It appears to be a light but hard lignite, burning briskly and with but little ash. He states (op. cit., p. 133) that it exists in large quantities, but the stream is shallow and has a bar at its entrance, and therefore the mineral could be gotten out only by means of lighters.

It may be mentioned that traces of lignite were found upon Wrangell Land by the *Corwin* party.

While referring to the subject of Alaskan paleobotany, it may be noted that a few species of fossil plants are enumerated[3] by Professor Lesquereux as collected at Sitka by E. W. Nelson, but some doubt exists as to the correctness of this locality, though the specimens are

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[1] Eighth Ann. Rept. U. S. Geol. Survey, Part II, 1889, pp. 924–926.

[2] Eleventh Census, Alaska, pp. 132–133.

[3] Proc. U. S. Nat. Mus., Vol. X, 1887, pp. 35–37.

doubtless Alaskan. J. Felix[1] has described a fossil wood (*Pityoxylon inæquale*) from the "basalt mountain south of Danaaku," Alaska, a locality about 50 miles north of the northern end of Lynn Canal, in southeastern Alaska. A general summary of what has been done in Alaskan paleobotany was published by Mr. F. H. Knowlton in 1894[2] and his list of the species known from these beds, with the additions made by our collections in 1895, bringing the list to date, is included in Appendix I to this report.

GENERAL DISCUSSION OF THE COALS OF ALASKA.

ECONOMIC CONDITIONS.

Between peat and lignite, lignite and brown coal, brown coal and bituminous coal, bituminous coal and anthracite, the differences are only of degree, and no absolutely characteristic differentiating definitions of them can be formulated which will be of universal application.

The Alaskan fossil fuels, as far as yet observed, belong to the group generally included under the head of lignite or brown coal. Taking the coals of Kachemak Bay, the coal of the Curtis seam is, according to the classification of Zincken,[3] earthy or fibrous brown coal, while that from the Bradley seam is in large part "glanzkohle." Nearly all the beds show successive or combined layers of both aspects. When the beds are cut by later volcanic dikes the coal in their vicinity is often converted into an anthracitic natural coke. This is reported to have occurred in Queen Charlotte Islands and at Herendeen Bay. In such cases the supply is always limited and the beds are disturbed more or less by faulting and pressure. The bright, clean, cubically breaking, brilliant "glanzkohle" is often mistaken by prospectors for anthracite, but has less specific gravity and a wholly different structure.

The fibrous brown coal retains many of the characteristics of the woody matter from which it was derived; the "grain" of the tree is often perceptible, and the blocks break up into elongated pieces like chips, rather than into angular fragments as does anthracite, or into cubical blocks as does the glance coal.

The brown coal, when scratched, gives a brownish streak, from which its name is derived, as the mass itself is black or almost black. The glance coal gives a blackish streak, and the intermediate qualities vary between the two.

The literature on the Pacific Coast lignites is not extensive. The first publication I have noticed, that of Brown,[4] barely alludes to them; and Zincken's monograph, already referred to, gives few details for this

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[1] Zeitschr. Deutsch. geol. Gesell., vol. 38, pp. 483–484, Leipzig, 1886.

[2] Proc. U. S. Nat. Mus., Vol. XVII, No. 998, pp. 207-240 and Pl. IX.

[3] C. F. Zincken, Die Physiographie der Braunkohle, Hannover, Carl Rümpler, 1867, 8°, x, 828 pp., 3 pls.

[4] On the geographical distribution and physical characteristics of the coal fields of the North Pacific Coast, by Robert Brown: Trans. Edinburgh Geol. Soc., 1869, pp. 1-23.

region, while the analyses, being absolute instead of proximate, are not available for comparison, and help little to estimate the practical economic value of the fuels described.

Bailey Willis has described the lignites of the Great Sioux Reservation,[1] between the Grand and Morean rivers, South Dakota, but their lack of economic value renders the account of only geological interest.

ANALYSES.

The search for published proximate analyses of lignites in general has been singularly unfruitful, nearly all the analyses found being absolute, and therefore of little economic value, and even when proximate, generally confined to a statement of the moisture, volatile matter, fixed carbon, and ash, even the sulphur being omitted.

In the course of the international survey of the boundary of the forty-ninth parallel, Dr. George M. Dawson was attached to the British party as geologist, and among the publications of the commissioners is one treating on the lignites of the region traversed.

Analyses of thirteen samples of lignite from the Souris, Porcupine, and Big valleys, in the vicinity of the forty-ninth parallel, are given by Dawson[2] and may fairly be compared with the Alaskan lignites, being probably of a not very different age and character.

The average of these analyses, computed for comparison, with the moisture estimated at 12 per cent, gives fixed carbon 41.10, volatile matter 41.41, and ash 5.55 per cent.

Of these lignites Dr. Dawson says:

The lignites, it will be observed, are on the whole uniform in composition, and contain an average amount of over 40 per cent fixed carbon when the water content is estimated at 12 per cent. They thus fall somewhat behind the lignites given in Table II, from Wyoming, Utah, etc., and which are found in proximity to the Rocky Mountains and parallel ranges, and have probably been somewhat improved by metamorphism simultaneous with their elevation. The lignites here described, however, gain some advantage, in a practical point of view, from occurring in a horizontal position and outcropping in the sides of valleys in such a way that they might be worked by simple adits, avoiding the expense and trouble necessary when vertical sinking has to be resorted to in the first instance, as in the case of some of the other localities named, where the beds are often highly inclined or nearly vertical.

It is a disadvantage that none of those yet found yield a coherent coke. * * * The lignites examined merely shrink somewhat in size during the expulsion of the volatile combustible matter, and turn out of the crucible in a dry, incoherent powder. The volatile matter is, as might be expected, comparatively poor in luminous gases, and the lignites would consequently be of little use in the manufacture of illuminating gas.

The ash is generally of pale colors; gray and white, passing into yellowish-white, being the prevailing shades. One or two only yield a deeply colored ash, which is then of a brick-red color. It is small in amount in most of the specimens, and does

[1] Bull. U. S. Geol. Survey No. 21, Washington, 1885, 8°, 16 pp., 3 pl., 1 map.

[2] Report on the Tertiary lignite formation in the vicinity of the forty-ninth parallel, by George M. Dawson: Brit. N. Am. Boundary Com., Geol. Rept. of Progress for the year 1873, Montreal, Lovell, 1874, pp. 27–31, 8°.

not usually appear of a nature to form troublesome clinker. The lignites when burning yield a peculiar empyreumatic odor, but no smell of sulphur, and indeed, as might be foreseen from the nature of the ash, the quantity of sulphur present is very small. * * *

The lignites do not appear to be suited for smithy purposes, and the smiths who tried them reported it difficult to obtain a welding heat. The same fault has been found, I believe, with even the best classes of similar fuels found in the vicinity of the Union Pacific Railway, and arises, no doubt, from the great proportion of volatile, combustible matter to fixed carbon, and the quantity of hygroscopic and combined water. As the lignites do not coke, they would appear to be unsuited to the smelting of iron in the blast furnace, though it is possible they might be economically employed for this purpose in the raw state, especially if mixed with a proportion of wood charcoal and burned in furnaces of not too great height. (Excellent charcoal is, I believe, made from similar lignites in Germany, by treating them in coking ovens in the state in which they are extracted from the mine.) They are perfectly suited for puddling iron, and the metallurgical treatment of various ores if burned in gas furnaces. Similar fuels have already been extensively employed in this way at Golden City and other localities in Colorado, and in the mining districts of the Southern Rocky Mountain region, and appear several years ago to have commanded prices ranging from $2 to $4 per ton at the pit's mouth. Similar and even inferior lignites are extensively used for steam purposes in various parts of the world.

The following table is a portion of that given for comparison by Dawson as Table II:

Composition of lignites from various States and countries.

Locality.	Moisture.	Fixed carbon.	Volatile matter.	Ash.	Analyst.
Average air-dried wood	18.55	25.69	53.99	1.77	
American lignites:					
1. Golden City, Colo	13.43	45.57	37.15	3.85	J. T. Hodge.
2. Carbon, Wyo	6.80	49.72	35.48	8.00	Do.
3. Evanston, Utah	8.10	47.67	34.60	9.67	O. D. Allen.
4. Murphys, Colo	13.83	44.44	35.88	5.83	J. T. Hodge.
5. Chestnut R., Montana	3.00	43.50	41.50	12.00	A. C. Peale.
6. Marshal mine, Boulder, Colo., average of 5.	16.00	41.50	38.00	4.50	A. L. Ford.
7. Van Dyke, Wyo	8.12	53.23	36.65	2.00	J. T. Hodge.
European lignites:					
8. Zsemle, Hungary	12.60	55.20	27.85	4.35	Schrotter.
9. Wildsthut, Austria	26.15	39.12	19.15	15.58	Regnault.
10. Dax, France		44.11	50.80	4.99	Schrotter.

Dr. Dawson remarks that No. 7 was regarded by Hodge as equal to the best lignite of the Rocky Mountain region. It has more moisture and less ash than the Alaskan lignite from Amalik Harbor, which, on the other hand, has only 0.75 per cent of sulphur, while that of Van Dyke has probably three times as much.

The difference for practical purposes, however, is trifling, and the

Amalik Harbor lignite stands higher in fixed carbon and lower in moisture and sulphur than any other American lignite, except the Van Dyke, of which I have succeeded in finding a published analysis. It is surpassed in these qualities only by a few European and New Zealand varieties of brown coal or lignite, and has less moisture than even any of these.

The most fruitful source of information about the Pacific coals is a little book by Watson A. Goodyear,[1] who has edited the chapter on the coals of California for the report of the State Mining Bureau for 1888.[2] This, while not monographic, and rather brief, is perhaps the best general account of these coals which is accessible to the general reader.

An early account of the Mount Diablo lignites, with some analyses, which we have included in our tabulation, is given by Prof. J. D. Whitney[3] in his Geology of California.

Analyses of Pacific Coast lignites.

[c=coherent coke; its absence=noncoherency.]

Locality.	Authority.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Pebble Creek, Columbia County, Oreg.	U. S. G. S	10.03	43.40	29.98	16.59	3.69
Pebble Creek, East Fork, Columbia County, Oreg.	do	12.23	42.47	34.29	11.01	3.19
Pebble Creek, Upper Fork, Columbia County, Oreg.	do	10.83	41.05	c 43.17	4.95	2.47
Pebble Creek, East Fork, Columbia County, Oreg.	do	10.07	44.52	32.18	13.23	3.97
Hodge Creek, Clatsop County, Oreg.	do	8.08	41.26	c 46.81	3.85	1.30
Do	do	8.86	40.06	c 46.79	4.29	1.31
Coal Creek, Clatsop County, Oreg.	do	8.91	41.54	c 47.23	2.32	0.38
Shaw mine, Lincoln County, Oreg.	do	8.11	41.15	33.59	17.15	0.95
Yaquina basin, Lincoln County, Oreg.	do	8.53	39.95	c 45.79	5.73	2.00
Callahan's mine, Douglas County, Oreg.	do	1.96	43.68	51.11	3.25	1.66

[1] The Coal Mines of the Western Coast of the United States, San Francisco, Bancroft, 1877. 8°, iv, 153 pp.

[2] Reports of California State Mining Bureau. Vols. I–XI, 8°, 1880–1895. These reports contain coal data as follows:

II. Receipts at San Francisco of Pacific Coast coals, 1880–81, p. 25.

IV. Report on coals of the Pacific Coast, pp. 255–279.

V. Statistics of yield of Mount Diablo mines and analyses, pp. 102–105.

VII. Report on California coals, by W. A. Goodyear, pp. 117–178.

VIII. Notice of Livermore (Cal.) coals, pp. 26–30.

IX. Coal product of the State, pp. 323.

X. Corral Hollow and Livermore coal field, a report by W. A. Goodyear, pp. 91–95; Notice of Mount Diablo coal mines, p. 165.

I am also indebted to the director of the bureau for an opportunity to examine manuscript coal statistics and analyses in the possession of the office, some of which are printed in the accompanying table of Pacific Coast lignites.

[3] Geological Survey of California, Geology, Vol. I, 1865, pp. 27–31, 4°.

Analyses of Pacific Coast lignites—Continued.

Locality.	Authority.	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Beaver Hill mine, Coos County, Oreg.	U. S. G. S	10.42	42.21	43.18	4.19	0.69
Newport mine, Coos County, Oreg.	do	11.94	41.48	37.85	8.73	1.32
Seattle, Wash	Hanks	11.66	35.49	45.98	6.44	0.43
Do	do	6.70	38.32	47.99	6.49	
Do	Symington	5.00	40.00	50.00	5.00	
Wellington, British Columbia	do	4.00	30.25	50.75	15.00	
Do	do	4.00	34.00	49.50	12.50	
Nanaimo, British Columbia	J. D. Whitney	2.98	32.16	46.31	18.55	
Bellingham Bay, Washington	do	8.39	33.26	45.69	12.66	
Coos Bay, California	do	20.09	32.59	41.98	5.34	
San Mateo, Cal	do	17.54	35.93	43.00	3.53	
Mount Diablo, California	do	13.47	40.36	40.68	5.52	
Do	do	14.69	33.89	46.55	4.58	
Do	do	13.84	40.27	44.92	0.97	
Do	do	14.13	37.38	44.55	3.94	
Corral Hollow, California	do	20.53	35.62	36.35	7.50	
Do	U. S. G. S	9.95	47.64	30.45	11.96	4.59
Livermore mine, California	Price	18.08	39.30	35.61	7.01	
Do	do	20.78	31.00	42.46	5.70	
Summit mine, California	W. D. Johnson	16.00	41.75	34.00	8.25	
Willits, Mendocino County, Cal	Hanks	9.00	10.00	41.75	39.25	
Del Gabian, San Benito, Cal	do	18.40	31.15	30.00	20.45	
Tejon Pass, Kern County, Cal	do	10.47	34.60	44.86	10.07	
Panoche Pass, Kern County, Cal	do	13.73	31.73	31.54	23.00	
Cajon Pass, San Bernardino County, Cal.	do	9.67	27.67	46.53	16.13	
Lexington, Santa Clara County, Cal.	do	16.50	29.50	47.00	7.00	
Santa Clara mine, Los Angeles County, Cal.	do	7.87	29.93	49.53	12.67	
Cheney mine, San Diego County, Cal.	do	10.00	30.40	35.35	5.36	
Do	do	23.00	40.27	46.82	11.25	
Average		11.55	36.13	42.10	9.79	

Analyses of Californian brown coals.

Locality.	Moisture.	Volatile matter not moisture.	Fixed carbon.	Ash.
Priest Valley:				
Drabble mine—	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Upper tunnel, upper vein	11.25	38.25	38.50	12.00
Lower tunnel, upper vein	13.25	33.90	38.60	14.25
Upper tunnel, lower vein*	13.25	37.65	36.60	12.50
Lower tunnel, lower vein*	13.00	37.25	31.50	13.25
Stone Canyon mine (coherent)	5.25	39.75	49.25	5.75

Analyses of Californian brown coals—Continued.

Locality.	Moisture.	Volatile matter not moisture.	Fixed carbon.	Ash.
Coalinga.				
San Joaquin mine—	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Little vein	12.00	37.75	39.75	10.50
Big vein	11.25	40.25	31.25	17.25
California mine—				
Little vein	13.25	41.75	35.00	10.00
1,000 feet in	11.25	48.50	31.40	8.85
Mount Diablo:				
Central mine—				
Belshaw vein	13.00	36.00	48.00	3.00
Clark vein	13.47	40.36	40.68	5.52
Black Diamond vein	14.69	33.89	46.85	4.58
Walker Valley:				
Shimmin's prospect (soft coke)	0.50	17.50	22.00	60.00
Middle Fork Eel River:				
Main tunnel	8.00	39.25	46.25	6.50
Incline, 20 feet down, cropping in river	7.50	17.75	47.75	27.00
Top streak	6.75	40.00	47.50	5.75
Bottom streak	6.25	31.50	46.25	16.00
Round Valley:				
Float (coherent)	8.00	48.00	40.75	3.25
Mill Creek*	10.25	44.75	41.50	4.00
Mad River:				
Cropping on Marshe's place	10.25	45.00	29.50	15.75
Harpst mine (hard coke)	5.50	21.75	28.75	45.00
Maple Creek:				
Cropping in gulch above Crogan Gulch	14.25	53.75	29.50	2.75
Cropping in Crogan Gulch	14.00	49.80	32.95	3.25
Preston mine	12.25	50.75	31.00	6.00
Poison Camp:				
Cropping	9.50	41.00	48.40	1.10
Lancha Plana				
Orr mine	7.50	47.75	20.50	24.25
Garberville:				
Float from Buck Mountain Gulch* (soft coke)	7.60	46.90	43.25	2.25
Cropping near Mrs. Ray's house	10.10	51.80	31.00	7.10
Hydesville:				
Van Duzen River float	8.75	51.50	35.50	4.25
Hyampom Valley:				
Shaft 2 miles above post-office	12.25	42.55	41.60	3.60
Cropping on west side of river	10.50	38.65	24.15	26.70
Cropping in river	11.30	40.50	39.70	8.50
Hay Fork Valley:				
Lower bed, lower vein	9.10	34.25	19.15	39.50
Lower bed, upper vein	11.25	47.00	38.25	3.50
Cropping in hills	14.00	39.20	31.05	15.75
Upper bed, containing rosin	10.10	51.80	31.00	7.10
Eel River:				
East of Covelo (hard coke)	2.00	15.50	25.25	57.25

Analyses of Californian brown coals—Continued.

Locality.	Moisture.	Volatile matter not moisture.	Fixed carbon.	Ash.
Corral Hollow:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Main tunnel	16.00	39.00	36.00	11.00
Shaft	17.00	38.00	37.00	8.00
Shaft cannel coal (coherent)	6.00	57.00	24.00	13.00
Ione:				
Newman ranch	15.00	37.75	38.50	8.75
Mine No. 3—				
Sample No. 1	7.00	33.35	11.85	47.80
Sample No. 2	14.00	42.40	34.35	9 25
Sample No. 3	12.65	41.60	28.00	17 75
Sample No. 4	12.60	40.60	26.55	20.25
Elsinore:				
Robinson & Rawlins mine	15.50	40.00	29.50	15.00
Dolbeer & Hoff mine—				
Poorest coal	9.00	38.50	34.25	19.25
Best coal*	15.40	43.60	27.90	13.10
Cheney mine	19.00	46.50	21.90	12.60

The above analyses are condensed from the Twelfth Annual Report of the State Mineralogist, pp. 64-65, Sacramento, Cal., 1894. They were made by Mathyas and W. D. Johnson, chiefly by the former. When the coal has any coking quality the fact is indicated in parenthesis after the locality name. Those coals followed by an asterisk give a black powder when crushed, the others a brown powder.

To enable the reader to make his own comparisons, I have compiled the following tables:

Table I. This recapitulates the analyses made under the auspices of the United States Geological Survey of the Alaskan lignites, to which is added Newberry's analysis of the lignite brought from Port Graham by Captain Howard in 1868. These analyses are of coal taken from the seam and tied up in bags of stout duck, and analyzed immediately on arrival at headquarters. The moisture (except in Newberry's specimen, which had been dried for a year in a museum case) is probably about the normal for coal treated in the ordinary way of commerce.

Table II. This table gives the percentage of ash, sulphur, oxide of iron, lime, and phosphorus for the whole coal, and the oxide of iron, lime, and phosphorus pentoxide of the ash, in the four most important Cook Inlet lignites, with an analysis of the Corral Hollow coal, recently opened, for comparison.

Table III gives the average composition of the Cook Inlet lignites, and Table IV, the average of 39 other Pacific Coast lignites, for comparison. Lastly, Table V gives statistics of composition of 35 of the principal lignites from all parts of the world, for comparison with the previously mentioned Pacific and Alaskan varieties.

TABLE I.—*Analyses of Alaskan lignites.*

Locality.	Authority.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
McCluskey seam, Kootznahoo	U. S. G. S.	2.44	44.75	47.93	4.88	0.67
Sepphagen seam, Kootznahoo	do	1.66	35.40	31.80	31.14	0.32
Sullivan seam, Kootznahoo	do	0.82	21.86	35.52	41.80	0.51
Mitchell seam, Kootznahoo	do	2.37	31.73	30.89	35.01	0.47
De Groff seam, Kootznahoo	do	2.57	55.44	29.75	12.24	0.89
Bradley seam, Cook Inlet	do	12.64	43.36	37.14	6.86	0.49
Eastland seam, Cook Inlet	do	11.72	46.50	34.64	7.14	0.40
Do	do	10.35	52.22	34.58	2.85	0.17
Do	do	11.59	50.70	30.84	6.87	0.22
Curtis seam, Cook Inlet	do	11.67	52.37	21.01	14.95	0.46
Port Graham, Cook Inlet	Newberry	1.25	39.87	49.89	7.82	1.20
Red River, Kadiak	U. S. G. S.	12.31	51.48	33.80	2.41	0.17
Amalik Harbor, Alaska Peninsula	do	1.62	36.56	52.92	8.90	0.75
Chignik River, Alaska Peninsula	do	1.89	41.47	48.46	8.18	1.71
Unga upper seam	do	11.26	40.51	41.24	6.99	2.17
Unga, lower seam	do	10.58	66.21	15.26	7.95	0.56
Herendeen Bay	do	3.43	39.00	47.40	10.17	0.44

TABLE II.—*Constituents of Cook Inlet lignites.*

Locality.	Percentage of whole coal.					Per cent of ash.		
	Ash.	Sulphur.	Iron oxide.	Lime.	Phosphorus.	Fe_2O_3	CaO	P_2O_5
Bradley seam	6.86	0.49	0.37	0.88	0.021	5.34	12.88	0.70
Eastland (1)	7.14	0.40	0.45	1.95	0.069	6.28	27.37	2.21
Eastland (2)	6.87	0.22	0.36	2.12	0.100	5.17	30.86	3.35
Curtis seam	14.95	0.46	0.32	2.15	0.132	2.13	14.39	2.03
Corral Hollow, California	11.96	4.59	1.63	3.55	0.014	13.62	29.63	0.28

TABLE III.—*Average composition of Cook Inlet lignites.*

	Per cent.
Five varieties:	
Moisture	11.59
Volatile matter	49.03
Fixed carbon	31.64
Ash	7.73
Sulphur	0.392
Four varieties:	
Phosphorus	0.080
Lime	1.775
Iron oxide	0.375

TABLE IV.—*Average composition of other Pacific Coast lignites.*

	Per cent.
Thirty-nine varieties:	
Moisture	11.55
Volatile matter	36.13
Fixed carbon	42.10
Ash	9.79
Fourteen varieties:	
Sulphur	1.71

TABLE V.—*Composition of foreign lignites and brown coals.*(*a*)

Locality.	Moisture. *b*	Volatile matter.	Fixed carbon.	Ash.	Analyst.
	Per cent.	*Per cent.*	*Per cent.*	*Per ct.*	
Suderoë, Faroe Islands		37.50	24.50	38.00	Durocher.
Habichtwald, Hesse Cassel		42.49	54.18	3.33	Kühnert.
Habichtwald No. 2, Hesse Cassel		42.10	52.98	4.92	Do.
Habichtwald No. 3, Hesse Cassel		41.84	54.96	3.20	Do.
Rigenkuhl, Hesse Cassel		47.01	51.70	1.29	Do.
Stillberg, Hesse Cassel		42.27	50.78	6.95	Do.
Malvern No. 1, New Zealand *c*	11.79	35.42	49.99	2.80	
Malvern No. 2, New Zealand *c*	19.20	30.92	47.70	2.20	
Rakaia (glance), New Zealand *c*	6.76	21.27	64.51	7.46	
Rakaia (brown), New Zealand *c*	24 09	21.61	50.12	4.18	
Westport No. 1, New Zealand *c*	2.60	37.17	56.01	4.22	
Westport No. 2, New Zealand *c*	3.96	34.94	57.92	3.18	
Whangoree (glance), New Zealand *c*	8.01	38.68	50.11	3.20	
Waikato, New Zealand *c*	19.82	29.97	50.01	2.20	
Otago, New Zealand *c*	19.20	30.10	45.30	5.40	
Okoko, New Zealand *c*	22.21	33.74	39.83	4.22	
Disco Island, Greenland *d*		50.60	39.56	9.84	
Val Pineau, France		57.00	36.50	6.05	Berthier.
Gurdanne, France		43.00	41.80	15.02	Do.
Fureau, France		53.00	36.00	11.00	Do.
St. Martin de Vaud, France		44.00	45.00	11.00	Do.
Koep Fuarch, Holland		47.00	41.00	12.00	Do.
Elbogen, Holland		69.30	24.00	6.70	Do.
Alphie, Holland		56.50	27.50	16.00	Do.
Triphilis		51.00	31.00	18.00	Do.
Konnin		53.50	34.00	12.50	Do.
Baffins Bay		46.00	58.80	5.20	Do.
Utweiler, Elsass		31.80	67.30	0.90	Do.
Edon (Charente), France		50.00	39.00	11.00	Do.
St. Lon (B. Pyr.), France		46.00	48.40	5.60	Do.
L'Enfant-dort (B. de Rh.), France		46.80	49.30	3.90	Do.
Minerve (Aube), France		57.40	32.60	10.00	Do.
Dauphin (B. Alpes), France		49.00	43.60	7.40	Do.
Marseilles, France		46.80	49.30	3.90	Dufrenoy.
Dauphiné, France		49.00	43.60	7.40	Do.

a These fig es are extracted from Mills and Rowan, Fuel and its Applications, 8°, London, 1889.

b The analy s which show no figures in the column for moisture are supposed to represent the dry fuel.

c See Jour. Iron and Steel Inst., London, Vol. I, 1886, p. 246.

d Sulphur, 1.3848.

From these tables it is deducible that the best of the Alaskan lignites—that of Amalik Harbor—stands very high indeed among Cenozoic coals as regards its composition. The Cook Inlet coals have about an average amount of moisture, rather less than the average amount of ash, remarkably little sulphur, an excess of volatile combustible matter, and a deficiency of fixed carbon. The lower layers are, as might be expected, the best, but none of them have as much fixed carbon as the better class of lignites from the region of Kadiak and the peninsula, where the rocks have been subjected to greater disturbance, involving greater pressure on the seams of lignite.

TESTS AND CONCLUSIONS.

Turning from the theoretical and chemical considerations to results obtained in practice, the following data have been brought together:

Coal from the best of the Kootznahoo Inlet beds, which have been designated the McCluskey outcrop, was tried in steam launch No. 18 of the United States Coast and Geodetic Survey steamer *Patterson*, under coiled tubular boiler. According to the informal report of the engineer, it burned well and developed about three-fourths the steaming value of the Wellington (B. C.) coal usually used. It was decidedly better than the Comox coal.

During part of the expedition of 28 days' cruising on the steam tug *Kodat*, in July and August, 1895, we were obliged to burn coal from the Bradley seam, Kachemak Bay, Cook Inlet, which was dug out of the beach at low water with crowbars and burned as it was, covered more or less with barnacles and seaweed. This coal, being under water most of the time, must have had a larger percentage of moisture than the normal amount belonging to it. The opinion of the engineer of the *Kodat* was to the effect that this lignite did from 60 to 75 per cent of the duty of Wellington (B. C.) coal.

Several hundred tons of coal from Eastland Canyon, Kachemak Bay, were imported into San Francisco by the Alaska Mining and Transportation Company in 1895, and distributed to various manufacturing establishments for trial. Among these was the foundry of Messrs. W. T. Garrat & Co., well known as the principal brass founders of the Pacific Coast. I was informed by their manager that this coal, to the amount of 50 tons, had been in use for making steam in their establishment, and was regarded by them as a very fair article of steaming coal. When a good fire was kept up they used 2,600 pounds in a given time, during which they would have used 2,200 pounds of Comox (B. C.) coal. With a low fire and small pressure of steam the amount used was 2,240 pounds to 1,350 of Comox. They stated that if the Cook Inlet coal could be furnished at a price corresponding to its relative efficiency compared with the British Columbian coal they should be glad to make regular use of it.

By permission of the Secretary of the Navy, and at the request of some New York parties, Lieut. R. P. Schwerin, in April, 1891, proceeded to the Cook Inlet region to examine the coal fields. The party was provided with a diamond drill and examined numerous seams. From four localities in particular, one of which was the McNeil Canyon, Kachemak Bay, 50 tons of coal each were mined and brought to San Francisco. Lieutenant Schwerin informed me that during the entire summer this coal was used under the boiler and for cooking in camp and aboard ship. It gave very satisfactory results for stationary purposes, though the coal slacks into chip-like fragments rather rapidly after exposure to a dry atmosphere. He induced the Southern Pacific Company of California to make a test of the coal on their locomotives, a purpose for which it proved unfit owing to its sparking tendency, which under forced draft was very pronounced in spite of the use of fine netting over the stacks. There was no trouble of this kind when used under a stationary engine or in a cooking stove.

The following summary of the data of the test, prepared September 29, 1891, was kindly furnished to Dr. Becker by Lieutenant Schwerin, who is now one of the staff of the Southern Pacific Railway organization. The kinds of coal with which the Cook Inlet lignite was compared were the ordinary Nanaimo coal from Vancouver Island and bituminous Cardiff coal imported as ballast by wheat ships.

Comparative test of Cook Inlet, Nanaimo, and Cardiff coals.

	Cook Inlet.	Nanaimo	Cardiff
Number of trips	2	2	4
Average number of miles per trip	86	168	86
Average gallons water used per trip	3,734	13,836	2,989
Average pounds fuel per trip	6,982	18,551	3,601
Average number loaded cars per trip	6.2	11.98	6
Average number empty cars per trip	....	1.401	75
Average tons weight loaded cars per trip	155.35	....	139
Average tons weight empty cars per trip	....	....	21.25
Average tons weight train without the engine and tender	155.35	301.47	160.25
Gallons water used per ton of train	24.04	45.895	18.653
Pounds fuel used per ton of train	44.94	61.535	22.473
Water evaporated per pound of fuel	4.46	6.215	6.917
Fuel burned per gallon of water evaporated	1.87	....	1.205
Average steam pressure	130.5	143	150.3
Average temperature of air	....	....	52°
Average temperature of feed water	68°	....	57°
Average temperature of steam	355.6°	....	365.7°
Area of grate, in square feet	16.87	25.6	16.87

Comparative test of Cook Inlet, Nanaimo, and Cardiff coals—Continued.

	Cook Inlet.	Nanaimo.	Cardiff.
Average fuel per hour per square foot of grate, pounds			54.215
Total heating surface	1.325	1,288	1,325
Pounds fuel burned per hour per square foot of heating surface			.69
Pounds fuel burned per ton per mile	.5226	.3663	.2613
Equivalent evaporation from temperature of feed water	5.33	7.507	8.369
Average number of miles run per ton fuel burned	24.635	18.112	47.762
Per cent value of fuel from evaporation	63.687	89.7	100

It thus appears that the Cook Inlet coal, under these conditions, has 71 per cent of the heating effect of Nanaimo coal and 63.7 per cent of Cardiff bituminous, a result which agrees fairly well with that derived from the other tests above mentioned.

The following table, adapted from Goodyear (op. cit., p. 164), shows the relative value as fuel of the Pacific Coast lignites, to which I have added the Cook Inlet variety.

Table of relative values of Pacific Coast lignites.

Locality.	Value.
Mount Diablo, Black Diamond, best	1.000
Bellingham Bay, Washington	1.148
Seattle, Wash., average of three tests	1.229
Nanaimo, British Columbia (two tests)	1.306
Wellington, British Columbia (two tests)	1.351
Cook Inlet, average of four tests	0.927

Although, as far as composition goes, the lignites of Amalik Harbor, Chignik River, and McCluskey seam, Kootznahoo, are all of a better quality than tne best of the Kachemak Bay lignites, nevertheless I have selected the latter for discussion in connection with the general economic status of the Alaskan coals. Many things go to modify the economic value of a coal deposit beside the quality of the mineral as fuel. The undisturbed or broken condition of the strata as a whole; the thickness of the seams; the presence or absence of a good roof rock above them; the dip of the strata; the accessibility of wood for timbering, and its cost; facilities for transportation and distance of the market, and the ease or difficulty of procuring mining labor, each may make or mar the future of a mine. And since the profit on a single ton of coal is always small, the presence of the fuel in sufficient quantity to ship by the thousands of tons is essential to profitable working on a large scale.

In the case of the mines at Kachemak Bay, there is an excellent harbor open at all seasons of the year; the coal seams are above the sea level for the most part, and nearly horizontal; several of them are thick enough for economic working; the strata appear to be free from excessive disturbance, and very little faulting could be noted; there is abundance of timber on the table-land for timbering the tunnels; no shafting, or but little, seems called for in working; and the coal could be carried in many cases to the beach or wharf by gravity. The quantity is abundant and the quality fairly good for stationary engines, steamship use, or household purposes.

The roof rock is generally weak, and timbering would be necessary. The floor is often of an almost clayey consistency. The site of the mines is rather distant from a market, and there is no available local labor. The region is subject to severe storms during the spring and fall seasons.

The conditions seem sufficiently good to warrant the conclusion that the Cook Inlet lignite might find a market in California if mined in such an economical way as to be sold for a price equivalent to its relative efficiency compared with competitive fuels. It has the advantage of the cheap coals of Mount Diablo and Corral Hollow, in that it is not, like them, so permeated with marcasite (sulphur) as to be liable, when stored, to spontaneous combustion. While it slacks on exposure to dry air, this does not seriously affect its value as fuel; and a large quantity which I saw at Woody Island, Kadiak, which had been some months exposed to the sun and rain, had not slacked worse than the Nanaimo coal which lay in the same dump. It has the advantage of being clean to handle and making little smoke. The gases given off are less offensive than those from the Corral Hollow or Nanaimo coals. In drying, it assumes a dull earthy or fibrous appearance, which, to one accustomed to the more brilliant coals, is unpromising, and it would doubtless have to overcome some prejudice among private consumers on this account. At any rate, there can be no doubt that an investment in it would fail to be profitable unless the work was carried on on a large scale and with something like the economy and business efficiency which characterize coal mining in the Eastern States. With such management there seems to be reason to hope that these lignites may have a commercial future.

The McCluskey seam at Kootznahoo is too little developed to allow of any estimate of its extent, of the condition of the adjacent strata, or of the quantity of coal which may be available.

The Amalik Harbor seam is too thin to admit of profitable mining, notwithstanding the high quality of the coal. But this vicinity is almost unknown, and further explorations might develop more abundant deposits. Such exploration would seem to be advisable, if only for the convenience of local consumers.

In conclusion, it may be noted that in 1890, according to the Eleventh Census, coal was imported into Alaska to the amount of 11,178 tons, of which 7,038 tons were cargo. The quantity needed is rapidly increasing, and with the increase of mills and reduction works must continue to do so. For many purposes the Alaskan lignites are quite good enough, provided they can be cheaply furnished, but up to the present time the mines of British Columbia have fully occupied the field.

GENERAL NOTES ON THE TERTIARY GEOLOGY OF ALASKA.

As might be expected, the geology of this Territory is most imperfectly known, but the little which has been recorded leads to the inference that to a great extent the operations of mountain-building forces and the deposition of sediments along the coast of Alaska, south of and including the peninsula, were carried on in a similar and probably generally synchronous manner from Mexico to Bering Sea.

So far we have not been able to find any record of the discovery of marine fossils belonging to the Eocene in Alaska, though of the marine Miocene and earlier leaf-bearing beds, with lignitic coal, etc., there are abundant instances.

GENERAL NOTES ON THE ROCKS.

In general, along the southeastern coast of Alaska, the sequence of the rocks where undisturbed appears to be about as follows, in descending order:

1. Soil and Pleistocene beds.

2. Brown Miocene sandstones, with marine shells, cetacean bones, and waterworn teredo-bored fossil wood (Astoria group, Nulato sandstones, Crepidula bed).

3. Beds of conglomerate, brown and iron-stained, alternating with gravelly and sandy layers, the finer beds containing fossil leaves of Sequoia and other vegetable remains (Kenai group, Unga beds).

4. Bluish sandy slates and shales, with a rich plant flora, interstratified with beds of indurated gravel, fossil wood, and lignitic coal (Kenai group).

5. Metamorphic quartzites and slaty rocks, with perhaps part of the lower Eocene (Tejon).

6. Granite and syenite in massive beds, usually without mica and apparently in most instances forming the "backbone" of the mountain ridges or islands, but occasionally occurring as intrusive masses, which have thrust up the metamorphic rocks above them into arches, cracking them, and filling the fissures with the syenitic material (Shumagin granite).

INTRUSIVE GRANITES.

Through all the Tertiary beds in various parts of the Territory are found penetrating volcanic dikes and larger outflows, sometimes injected between sedimentary strata and sometimes overflowing them, much as in California, Oregon, and elsewhere in western America. The later eruptions, mostly Pliocene and Pleistocene, are generally of a basaltic or andesitic character.[1]

The occurrence of intrusive syenite later than the metamorphic rocks and penetrating fissures in them is well exhibited at an arch of metamorphic rock near the beach at Granite Point, on the south side of the entrance to Sanborn Harbor, Nagai Island, in the Shumagin group, where it was noted by me while surveying the harbor in 1872. Instances of the occurrence of the syenite as a massive body forming the fundamental rock are offered in many places, as the Diomedes Islands, Bering Strait, and most of the mountain masses of the Siberian side of the same strait; the central ridge of the island of Unalaska; the islands and hills of the eastern Shumagins, as Little Koniushi Island, and of Port Althorp, Cross Sound, in the Alexander Archipelago.

The age of the intrusive granites is yet undetermined, but in the case of the mass forming the celebrated Treadwell mine of Douglas Island, near Juneau, Alaska, Dr. Dawson has referred the slaty rocks through which it has broken to the Vancouver series of Triassic rocks.[2] These questions more properly fall under the purview of Dr. Becker, and in this connection need not be considered further.

EARLY OBSERVATIONS ON ALASKAN GEOLOGY.

The Neozoic strata of southern Alaska were first noticed by Portlock and Dixon, who, on their voyage to the northwest coast of America in 1785, entered English Bay or Port Graham, Cook Inlet, and named it Coal Bay, from the lignitic beds exposed in its shores. In the following year the marine Miocene was observed by the naturalists of La Perouse's party, who collected in Lituya Bay, at the height of 200 toises above the sea, specimens of one of the large Miocene pectens.[3] The first general summary of existing knowledge of geology and geognosy of this region is comprised in the work of Grewingk,[4] who enumerates the localities for the Tertiary rocks, among others, and illustrates and enumerates many of the fossils. The paleobotany of the region

[1] See Dall, Note on Alaska Tertiary deposits: Am. Jour. Sci., 3d ser., July, 1882, Vol. XXIV, pp. 67–68.

[2] Notes on the ore deposit of the Treadwell mine, Alaska: Am. Geologist, August, 1889, pp. 84–93.

[3] Cf. Voy. La Pérouse, vol. 1, p. 395.

[4] Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nord-West-Küste Amerikas: Verhandl. der russ.-kais. mineral. Gesell. zu St. Petersburg für 1848–49, 351 pp., 8°. Separately issued by Carl Kray, St. Petersburg, 1850.

was subsequently treated of by Göppert[1] and Heer.[2] Later, Eichwald[3] reviewed the subject, and introduced a certain amount of confusion into the paleontological side of the question by referring to the Cretaceous (Turonian) all the marine Tertiary fossils described by Grewingk, many of which belonged to Miocene beds, but which Eichwald appears to have regarded as of the same age as the Tejon beds of California, which, following Gabb, in the Paleontology of California, he referred with the Chico to the Mesozoic epoch.

THE KENAI GROUP.

The coal-bearing Kenai beds, best exhibited on the shores of Kachemak Bay, Kenai Peninsula, Cook Inlet, but widely spread in British Columbia and over the coast of Alaska and its adjacent islands, are regarded by Heer as the equivalent of the Atane leaf beds of Greenland, the Spitzbergen Miocene plant beds, the Braunkohl of east Prussia and the lower Rhine provinces, and the lower Molasse of Switzerland.

THE UNGA CONGLOMERATE.

On the island of Unga, Shumagin group, Alaska, they are conformably overlain by the brown conglomerates with Sequoia, which are obviously younger and the result of a somewhat different series of conditions, though the sedimentation appears to have been measurably continuous. To these last the name of the *Unga conglomerate* has been given; but since in the present imperfect state of our knowledge we are unable to specify the exact horizon of most of the leaf beds reported by various observers, the whole series will be treated here under one head.

The localities at which the Kenai formation is known or believed to occur in Alaska have been already fully described, and therefore there is no need to recapitulate their distribution. That they also extend into British Columbia there is little doubt.[4] The leaf beds of northern Japan and of the Okhotsk Sea should also be compared.

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[1] Abhandl. der schles. Gesell. für vaterl. Cultur, II, 1861, p. 201, and 1867, p. 50.

[2] Flora fossilis Alaskana: Kongl. svensk. Vet.-Akad. Handl, Bd. 8, No. 4, Stockholm, 1869, 41 pp., 10 pl.

[3] Geogn.-pal. Bemerkungen über die Halbinsel Mangischlak und die Aleutischen Inseln. St. Peterburg Kais. Akad. Wiss., 1871, 8°, pp. 200, pl. XX; cf. pp. 88–137.

[4] Cf. Bull. U. S. Geol. Survey No. 84, p. 231, for beds described by Dawson. These beds are obviously to be referred to the Kenai group, since they contain essentially the same flora. Limnæa, Physa, and Sphærium have also been noticed at Vermilion Cliff. Localities for the occurrence of plant beds and lignites of the Kenai group in the southern part of British Columbia may be mentioned as follows: The vicinity of Okanogan Lake; the Coal Brook Indian Reserve on the North Thompson River (p. 113); Kamloops Lake (p. 114); Vermilion Cliff, 3 miles up the North Fork of the Similkameen River (p. 130), and also the South Fork (p. 132); on Ninemile Creek and Hat Creek (p. 121); 20 miles north of Osoyoos Lake, where 3,000 feet of sandstones and shales have been observed (p. 129); on Tenmile Creek coal is noted (p. 126), and also near the junction of Nicola and Coldwater rivers (p. 122); on the Fraser near Lillooet, and on the upper part of Kettle River (p. 160). Dawson also notes the complete absence of marine Eocene beds (p. 167).

See Dominion Geological Survey, Report of Progress for 1877–78, Montreal, Canada, 1879, pp. 1–188B, by Geo. M. Dawson (to which above page references refer), including a list of Tertiary plants from various British Columbian localities, by J. W. Dawson, LL. D., op. cit., pp. 186–188B.

For additional information on the Tertiary rocks of the interior of British Columbia see Rept. of Progress, Dom. Geol. Survey for 1871–72, p. 56; for 1875–76, pp. 70, 225; for 1876–77, pp. 75 and 112B.

CORRELATION OF THE KENAI SERIES.

Having indicated the extent and position of beds in Alaska belonging to the Kenai group, as far as our imperfect knowledge of them will permit, it is now in order to discuss their geological age upon the basis of the facts presented. This will of necessity be largely dependent upon data other than the similarity of flora, which has been conclusively shown to have little value as a test of synchrony between widely separated geological deposits. Of the 54 species enumerated from the Kenai Peninsula by Heer, 30 were previously known from Miocene strata in other parts of the world. Of those from Kuiu and Unga, 65 species, 31 were previously known as Miocene. According to Heer, no doubt can exist as to their Miocene age, in which conclusion Lesquereux agrees, remarking:

> The plants described by Heer, representing 56 species, are of marked interest by their intimate relation with those of Atane in Greenland on one side and with those of Carbon in Wyoming and of the Bad Lands of Dakota on the other. They comprise a small group which supplies an intermediate point of comparison for considering the march of the vegetation during the Miocene period from the Polar circle to the middle of the North American continent, or from the thirty-fifth or fortieth to the eightieth degree of latitude. The remarkable affinity of the Miocene types in their distribution from Spitzbergen and Greenland to the middle of Europe had already been manifested by the celebrated works of Heer. But the Alaska flora has for this continent the great advantage of exposing in the Miocene period the predominance of vegetable types, which have continued to our time and are still present in the vegetation of this continent. (Op. cit., p. 443.)

In his later publication on the same subject Lesquereux[1] remarks:

> Alaska has 73 species, of which 13 are found in the Bad Lands, 4 at Carbon (Wyoming), and 2 in the Chalk Bluffs (California). * * * Of the 13 species common to Alaska and the Bad Lands, 9 are Arctic, of these 6 are European also; and besides *Populus latior*, *P. glandulifera*, and *Juglans nigella* are European, but not yet found in the Arctic flora. The Bad Lands group, therefore, is truly Miocene, and shows scarcely any deviation from that of Alaska. The 3 species mentioned as not Arctic may be indicative of a somewhat warmer climate. * * * As the fossil floras of Carbon and the Bad Lands are related by 10 identical species and those of the Bad Lands and Alaska by 13, these three groups apparently represent the same stage of the North American Miocene. The flora of Carbon has only 4 species identified in that of Alaska; but this lesser degree of affinity may be ascribed to difference in latitude.[2]

Of the 73 species enumerated by Lesquereux from Alaska, 21 are tabulated by him as common to Greenland and Spitzbergen also, and 31 as common to the Miocene of Europe and Alaska.

The term Miocene, as used by Heer, seems to have been based primarily on the stratigraphic nomenclature of Switzerland. His method of inferring the age of a given plant bed from the fact of its showing a number of species equivalent with those of any Swiss bed would in-

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[1] Contributions to the fossil flora of the Western Territories, part 3, the Cretaceous and Tertiary Floras: Rept. U. S. Geol. Survey of the Terr., by F. V. Hayden, vol. 8, 1883, Washington, 4°; cf. Miocene Flora, pp. 219-277.

[2] Op. cit., p. 275.

variably lead to the conclusion that the possession of a flora in common is sufficient evidence of a general synchrony between the two formations. But Prof. L. F. Ward states that the vertical range of many fossil plants is very great, and that such conclusions can not safely be reached except by the aid of corroborative evidence in addition to a partial similarity of flora.

The beds of Carbon, Wyo., with which Lesquereux compared the Kenai group, are by Dr. C. A. White referred on stratigraphic grounds to the Laramie. Professor Ward[1] agrees with this conclusion, and in his tables places the Carbon beds between the typical Laramie and the Fort Union beds, all of which are included under the general term Laramie.

The newer leaf beds in Greenland have lately been regarded as Eocene by Mr. J. Starkie Gardner, and as equivalent in the main to the flora of the Basaltic (Eocene) beds of Britain.[2] The Spitzbergen beds would naturally follow those of Greenland. But the inferential reference of the plant remains of the Pliocene gravels of California to the Eocene by Mr. Gardner somewhat weakens the force of his opinion on other fossil floras, since it is impossible that the Californian plant remains can be Eocene.

I have already pointed out the probability that, if Miocene at all, the leaf beds of Greenland referred to would be synchronous with that geological epoch during which the old Miocene warm-water invertebrate fauna of the Atlantic Coast penetrated as far north as New Jersey.[3] Since that time a further study of the so-called Miocene of the Antilles, Central America, and the Gulf border of the United States has shown me that what has been hitherto called old Miocene, or warm-water Miocene, by me—the Miocene of writers on Antillean geology—is really Oligocene, and corresponds with the Oligocene of Bordeaux and other localities in Europe.

Since that time it is highly improbable that any temperate conditions, such as the flora would indicate for the Atane period, have obtained in the latitude of Greenland. In other words, the Greenland beds are not later than the Oligocene, though this does not preclude a reference of them to an older horizon, for during the Eocene also the conditions in the extreme north might have been favorable to such a flora.

In Alaska, at Cook Inlet, at Unga Island, at Atka, and at Nulato, in the Yukon Valley, we find the leaf beds of the Kenai group immediately and conformably overlain by marine beds containing fossil shells which are common to the Miocene of Astoria, Oreg., and to that of middle and southern California.

It is then certain that the Kenai leaf beds immediately preceded, and their deposition terminated with, the depression (probably moderate in

[1] Sixth Ann. Rept. U. S. Geol. Survey, for 1884–85, p. 539.

[2] Proc. Royal Soc. London, Vol. XXXVIII, 1885, pp. 22–23. See also Nature, vol. 20, 1879, pp. 10–13.

[3] Bull. U. S. Geol. Survey No. 84, 1892, p. 21.

vertical range) which enabled the marine Miocene fauna to spread over part of the antecedently dry land. Further researches along the Alaskan coast will doubtless enable us to determine whether the leaf beds themselves are underlain by marine Eocene beds or not. We know that the Aucella beds underlie the Kenai series, but whether there are any beds representing the marine phase of the Eocene between them is yet uncertain, though probable. Eichwald's references to the age of the Alaskan Neozoic marine fossils are more or less confused and should not be taken into account in any discussion of the subject, as he has referred most of them indiscriminately to the Cretaceous, by which he means Gabb's Chico-Tejon series.

What may be considered as reasonably certain is that the period during which in the Arctic regions the last temperate flora flourished was in a general way the same for all parts of the Arctic. It would seem highly improbable that a temperate climate should exist in Spitzbergen and not at the same time in Greenland and Alaska, or vice versa. If Alaska was covered by the sea at this time, we should find a temperate marine fauna; if it was dry land, a temperate flora; and so with the other Arctic localities; and these indications should, it would seem, represent an identical and synchronic phase of geological history in the Arctic regions.

In this connection the remarks of Prof. F. H. Knowlton[1] may be cited:

The geological age of these coal-bearing rocks, from which most of the plants enumerated in this paper came, has usually been regarded as Miocene. Heer, who worked up the first considerable collection of plants, referred them unhesitatingly to this horizon, and regarded them as the equivalent of the Miocene beds of Greenland, Spitzbergen, the Braunkohl of East Prussia, and the Lower Molasse of Switzerland. Lesquereux and at first Newberry do not appear to have seriously questioned their Miocene age. Of the 73 species enumerated by Lesquereux in his latest publication on Alaskan plants, 21 are found in Greenland and Spitzbergen and 31 in the Miocene of other parts of the world. These considerations show, as already pointed out under the discussion of the table, that the fossil flora of Alaska is inseparably connected with that of the Disco Island and Atanekerdluk beds of Greenland and the so-called Arctic Miocene of Spitzbergen and Sakhalin. Whatever is decided concerning them must apply with equal force to Alaska.

Mr. J. Starkie Gardner appears to have been the first to question the Miocene age of the Greenland beds,[2] or rather of the Arctic floras in general. The sequence of British Eocene floras is almost unbroken, and in studying them and their relations to the Miocene flora he was led to important conclusions. He says:

"There is no great break in passing from one to the other (Eocene to Miocene) when we compare them over many latitudes, and but little change beyond that brought about by altered temperature or migration. But if Tertiary floras of different ages are met with in one area, great changes on the contrary are seen, and these are mainly due to progressive modifications in climate and to altered distribution of land. Imperceptibly, too, the tropical members of the flora disappeared—that is to say, they migrated, for most of their types, I think, actually survive at the present day, many but slightly altered. Then the subtropical members decreased, and the

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[1] Proc. U. S. Nat. Mus., Vol. XVII, No. 998, 1894, pp. 237-239.

[2] British Eocene Flora, Part I, 1879, p. 8.

temperate forms, never quite absent even in the Middle Eocene, preponderated. As decreasing temperature drove the tropical forms south, the more northern must have pressed more closely upon them. The Northern Eocene, or the temperate floras of that period, must have pushed from their home in the far north more and more south as climates chilled, and at last, in the Miocene time, occupied our latitudes. The relative preponderance of these elements, I believe, will assist in determining the age of Tertiary deposits in Europe more than any minute comparisons of species. Thus it is useless to seek in the Arctic regions for Eocene floras as we know them in our latitudes, for during the Tertiary period the climatic conditions of the earth did not permit their growth there. Arctic floras of temperate and therefore Miocene aspect are in all probability of Eocene age, and what has been recognized as a newer or Miocene facies is due to their having been first studied in Europe in latitudes which only became fitted for them in Miocene times."

This change of view as to the age of the so-called Arctic Miocene, as proposed by Gardner, has already received considerable confirmation from American paleobotanists, and while it can hardly be regarded as settled, it may be accepted as extremely probable.

Dr. J. S. Newberry, in one of his latest publications, said:[1]

"I called the Fort Union group Miocene because I identified it with the plant-bearing beds of Mackenzie River, Disco Island, Greenland, etc., of which the flora had been studied by Prof. Oswald Heer and was by him called Miocene. This flora, to which I shall again refer, has since been shown by Mr. J. Starkie Gardner to be Eocene. The Fort Union flora has many species in common with the Eocene beds of the Island of Mull, Bournemouth, etc., and holds undoubtedly the same position."

On this same point Sir William Dawson says:[2]

"I have, also, while writing out the above notes for publication, received the paper of the same author (Gardner) on the Eocene beds of Ardtun, in Mull, and am fully confirmed thereby in the opinion derived from the papers of the Duke of Argyll and the late Prof. E. Forbes that the Mull beds very closely correspond in age with the Laramie. The Filicites hebridica of Forbes is our Onoclea sensibilis. The species of Ginkgo, Taxus, Sequoia, and Glyptostrobus correspond, and we have now probably found a Podocarpus, as noted above. The Platanites hebridica is very near to our great Platanus nobilis. Corylus MacQuarrii is common to both formations, as well as Populus arctica and P. Richardsoni, while many of the other exogens are generically the same, and very closely allied. These Ardtun beds are regarded by Mr. Gardner as Lower Eocene, or a little older than the Gelinden series of Saporta, and nearly of the same age with the so-called Miocene of Atanekerdluk, in Greenland. Dr. G. Dawson and the writer have, ever since 1875, maintained the Lower Eocene age of our Laramie, and of the Fort Union group of the Northwestern United States, and the identity of their flora with that of Mackenzie River and the upper beds of Greenland, and it is very satisfactory to find that Mr. Gardner has independently arrived at similar conclusions with respect to the Eocene of Great Britain."

Following out the argument suggested by Newberry and Dawson, that is, the relation existing between the plants of Alaska and Mackenzie River, and these in turn with the Canadian Laramie and the Fort Union group, we have important confirmatory evidence. The flora of the Mackenzie River beds, as worked out by Heer,[3] Schrœter,[4] and Dawson,[5] now numbers 30 species, and of these no less than 12, or 40 per cent, are found in Alaska. The 12 species common to Alaska are not rare or poorly defined in the Alaskan flora, but are in the main well marked and readily

[1] Trans. N. Y. Acad. Sci., Vol. IX, p. 1 of reprint.

[2] Trans. Royal Soc. Canada, 1887, p. 36.

[3] Fl. Foss. Arct. Vol. VI, 1 Abth., 3d Nr., Beiträge zur miocene Fl. v. Nord Canada.

[4] Op. cit. Vol. VI, 1 Abth., 4th Nr., Untersuchung ü. foss. Hölzer d. arct. Zone.

[5] Trans. Royal Soc. Canada, 1889, Fossil plants from Mackenzie and Bow rivers.

determinable forms, most of which are very abundant in individuals, as, for example, *Sequoia Langsdorfii, Taxodium distichum miocenum, Glyptostrobus Europæus* or *Ungeri, Corylus MacQuarrii, Populus arctica*, etc. A single species, *Pteris Sitkensis*, is confined to these two localities, and a number of other species, though known by different names, are closely allied, if not identical. There can be, therefore, little doubt as to the close relationship between the Alaskan and the Mackenzie River deposits.

The Mackenzie River flora, as already suggested, is in like manner closely related with the Canadian Upper Laramie, or Fort Union group, as it is called in the United States, about 30 per cent of the Mackenzie species being common to the two.

On turning to the table we find that 16 of the 55 Alaskan species are found in the Fort Union of the United States. By combining the species common to the Mackenzie River, Canadian Upper Laramie, and Fort Union, we have 22 or 23 of these species also found in the Alaskan beds.

Without going further into the subject, which indeed the present state of our knowledge will hardly warrant, it is safe to say with Sir William Dawson that "There can scarcely be any doubt that the flora of the Upper Laramie, of the Atanekerdluk series in Greenland, and of the Spitzbergen and Alaskan Tertiaries corresponds with the Eocene of Europe, and is also identical with Fort Union flora of the Missouri region, formerly regarded as Miocene.

In 1890, in discussing the Similkameen fossil plants, Sir William Dawson (op. cit., pp. 90–91) refers to their Miocene or possibly Oligocene aspect, and says:

Assuming the Similkameen flora to be Lower Miocene or Oligocene * * * it may further be affirmed that the Similkameen flora is closely allied to those described by Lesquereux as the Green River and Florissant floras, and which he regards as Oligocene or Upper Eocene.[1]

In working up the fossil insects of the Florissant and Gosiute Lake beds and of Green River, after discussing at length their relations, Scudder observes:[2]

The Gosiute Lake and the ancient lacustrine basin of Florissant were but little removed from each other, and the deposits of both are presumably of Oligocene age.

Still later, Sir William Dawson observes:[3]

I shall hope to show that we have in the Burrard Bay collections at least the pre-intimations of an early Tertiary flora occupying the space between the Cretaceous flora of the Nanaimo series and the Oligocene or Miocene flora of the Similkameen district.

The correlation of the Kenai group has been somewhat fully discussed because, up to very recently, authorities were almost unanimous in referring it to the Miocene. When we consider that the Oligocene Aturia bed is immediately and conformably overlain at Astoria, Oreg., by shales and sandstones undoubtedly equivalent to the Alaskan marine

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[1] It does not seem that this opinion was actually printed by Lesquereux, according to Professor Knowlton, and I find in the latest posthumous work of Lesquereux (The Flora of the Dakota Group. Mon. U. S. Geol. Survey, Vol. XVII, 1891, p. 245) that he still speaks of the Kenai beds as "the Miocene of Alaska and the Arctic regions." Possibly Sir William Dawson may have intended to refer to Scudder.

[2] Tertiary Rhynchophorous Coleoptera of the United States: Mon. U. S. Geol. Survey, Vol. XXI 1893, p. 9.

[3] Tertiary plants from the vicinity of the city of Vancouver, B. C.: Trans. Royal Soc. Canada, 1895, 2d ser., vol. 1, p. 140.

Miocene, and that the latter, in like manner, immediately and conformably overlies the Kenai group, it must be conceded that the view that the latter is Oligocene seems highly probable. If we add to this the weight of testimony as to the climatic conditions offered by the Oligocene marine fauna of the eastern United States, and the inferences drawn from the fossil insects and vertebrates, it would seem that we are justified in referring the Kenai group to the horizon of the Oligocene of European geologists.

The history of the paleobotany of Alaska and the constituents of the flora will be found elsewhere in this paper.

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The marine Neozoic beds overlying the leaf beds and conglomerates of the Kenai group appear indubitably referable to the Miocene series represented in the sandstones and shales of Astoria, though probably to the upper or newer portion of these beds. Eichwald[1] has confounded the unquestionably Neocene species figured by Grewingk with Cretaceous forms collected by Dr. Blaschke in Alaska, and referred the whole to the Turonian or Upper Chalk. The fact that nearly half of Grewingk's species are still found living is quite sufficient to establish the correctness of his original reference of them to the Tertiary, while they are derived, as previously shown, from beds overlying the leaf beds referred by Eichwald himself to the Miocene.

This does not conflict with the possibility that the Blaschke fossils, other than those described by Grewingk, may be referable to the Chico or other part of the Cretaceous, which is well known to occur in various parts of Alaska. It is possible that two of Grewingk's species, *Nucula ermani* and *Tellina dilatata* of Girard from Atka, may not belong to the same horizon as the others, though of this there is no proof, and the fossils themselves are not distinctive.

The table on pages 844 and 845 will indicate the known species and their relations.

[1] Geogn.-paleont. Bemerk., St. Petersburg, 1871, pp. 117-137.

It will be noted that of the 46 species known 12 belong to genera not now represented in such cold waters as those of Bering Sea, and of these. 2 species may possibly survive in Californian waters, the remainder being presumably extinct. The 19 species known to survive in the recent fauna are all forms which belong to northern waters, and are capable of surviving low temperatures, though sometimes ranging farther south. We may then conclude that in Miocene times the waters of this region were warmer than at present, and that the still colder epoch, near the end of the Pliocene or the beginning of the Pleistocene, weeded out the more delicate forms.

ENUMERATION OF SPECIAL LOCALITIES.

The localities where this fauna has been noticed and the marine beds more or less certainly identified will now be enumerated, beginning at the south.

On the south side of Dixon's entrance at Skookum Point, near Massett, Queen Charlotte Islands, Hon. J. G. Swan collected specimens, now in the National Museum, showing the presence of these beds.

The occurrence of beds of this age at Lituya Bay has already been alluded to. Cenotaph Island, in the bay, is chiefly composed of them, and Lamanon collected a species of Pecten with other marine fossils from a height of 200 toises above the sea level.

KADIAK.

On the island of Kadiak, north of Touki Cape, on the south coast from the shores of Igatskoi Bay, Wossnessenski collected a number of species of this fauna, which were embedded in a volcanic tuff about 10 feet above the sea. On the opposite side of the island, near the settlement of Uganak, similar beds were found containing analogous fossils.

At the head of the bay into which Red River falls Messrs. Becker and Purington obtained specimens of Cardium, etc., in a brownish sandstone evidently belonging to the horizon of the Astoria Miocene.

On the portage from Katmai Bay, across the ridge of Alaska Peninsula, on the trail to Naknek Lake, the same beds occur, from which Wossnessenski collected *Buccinum plectrum*.

CREPIDULA BED OF UNGA AND POPOFF ISLANDS.

One of the most prolific and best-known localities is situated at Zakharoff Bay (sometimes called Coal Bay), on the northern end of the island of Unga, one of the Shumagin group. A section on the west shore of this bay has already been described in detail, where the marine Miocene is represented in the upper part of the bluff by a layer of sandstone about a foot thick, densely crowded with specimens of *Crepidula prærupta* Conrad, sometimes referred to as *C. princeps* Conrad, which

Table showing distribution of the fauna of the Astoria group.[1]

Name of species identified.	Localities of Alaskan Miocene.												Miocene			Pliocene	Pleistocene.	Recent.	
	Nulato.	St. Paul Island.	Nushagak.	Port Möller.	Atka Island.	Unalaska.	Morzhowi.	Pavloff Bay.	Unga Island.	Katmai.	Kadiak Island.	Lituya Bay.	B. C.	Oreg.	Cal	Cal	Cal.	N.	S.
Ostrea tayloriana Gabb					×			×	×		×				×				
Ostrea veatchii Gabb					×				×						×	×			
Pecten pabloensis Conrad								×	×		×	×			×				
Mytilus middendorffii Grewingk									×		×								
Mytilus mathewsonii Gabb	×							×							×				
Modiola multiradiata Gabb	×		×						×					×	×				
Modiolaria nigra Gray									×										
Pectunculus kashevaroffi Grewingk		×							×		×								
Pectunculus patulus Conrad		×	×					×						×	×	×			×
Nucula tenuis Lamarck		×	×																
Nucula (Acila) ermani Girard		×			×														
Cardita aleutica Girard?					×														
Astarte borealis Gray		×																×	
Crassatella collina Conrad							×	×			×								
Cardium decoratum Grewingk		×			×			×	×		×		×						
Serripes gronlandicus Beck		×	×						×		×		×					×	
Liocyma fluctuosa Beck		×																×	
Tapes staminea Conrad		×						×							×	×	×	×	
Lioconcha sp.		×				×	×												
Tagelus sp.		×																	

[1] The synonymy of the species enumerated has been modernized, though the details of the process are reserved for a more appropriate occasion. All Grewingk's species are included, though some of them appear under names different from those he used. Of the forty-six species recognized in Alaskan beds, sixteen occur in the Miocene of British Columbia, Oregon, and California; of these a few are known from the Californian Pliocene, though when the latter fauna is better known this number will doubtless be much enlarged. The table has been enriched by an examination of specimens collected at St. Paul Island by Messrs. Palmer, Townsend, and Elliott; at Nushagak by the late C. W. McKay; and at Nulato, Zakharoff Harbor, Unga, and the adjacent shores of Popoff Island, by W. H. Dall.

Table showing distribution of the fauna of the Astoria group—Continued.

Name of species identified.	Localities of Alaskan Miocene.												Miocene.			Plio-cene.	Pleis-tocene.	Recent.	
	Nulato.	St. Paul Island.	Nushagak.	Port Möller.	Atka Island.	Unalaska.	Morzhowi.	Pavloff Bay.	Unga Island.	Katmai.	Kadiak Island.	Lituya Bay.	B. C.	Oreg.	Cal.	Cal.	Cal.	N.	S.
Soletellina sp		×																	
Tellina carlottensis Whiteaves	×	×	×			×							×					×	
Tellina alternidentata Brod. and Sby		×			×	×	×		×									×	
Macoma middendorfii Dall		×	×	×			×		×									×	
Macoma inconspicua Brod. and Sby		×											×			×	×	×	
Macoma nasuta Conrad			×										×	×	×	×	×	×	
Mactra albaria Conrad			×											×					
Lyonsia arenosa Möller		×																×	
Kennerlyia grandis Dall		×																×	
Mya præcisa Gould	×				×	×	×	×	×		×							×	
Mya truncata L. (var.)							×	×	×		×							×	
Saxicava arctica L		×	×		×		×	×	×		×							×	
Teredo sp		×	×						×										
Gastrochæna sp	×																		
Cylichna (alba Brown?)		×																	
Buccinum plectrum Stimpson		×				×				×								×	
Chrysodomus (altispira Gabb?)									×										
Odostomia sp		×																	
Litorina (sitkensis Phil. var.?)						×													
Galerus sp									×										
Crepidula prærupta Conrad									×				×	×	×	×			
Lunatia (pallida B. and S.?)		×																×	
Neverita saxea Conrad		×	×										×	×	×				
Natica clausa Brod. and Sby		×	×													×		×	
Margarita striata Brod. and Sby		×				×												×	
Margarita sp		×																	

has been erroneously identified with the recent *C. grandis* Middendorf. From the vast number of these shells of which the layer is made up the name Crepidula bed has been suggested for it.

This layer appears at a much lower level on the northern shore of the northeastern part of Unga, east from Zakharoff Bay. The sandstones lie horizontally, or nearly so, except where disturbed by intrusions of later basaltic lavas, which sometimes overflow the sedimentary beds or invade them vertically or laterally, altering the rock at contact and for some distance beyond the lavas.

On the shore of Popoff Island, next eastward from Unga and separated from the latter by a narrow strait, the same bed is continued, with a thickness varying from 6 inches to 2 feet, carrying oysters, Crepidula, Chrysodomus, etc. It is here separated from the conglomerates above and below by a layer, 10 to 25 feet thick, of hardly-consolidated sand. The upper conglomerate is of variable thickness and much altered by heat from a bed of lava and volcanic breccia 300 feet thick which overlies it. The special character of the igneous material varies rapidly from point to point horizontally and vertically. The lower part seems more like a cooked conglomerate of pieces of clay-porphyry in a basaltic matrix, while the upper portion is composed in part of sharp fragments of porphyrite and dolerite cemented by a thin, glossy, vitreous lava. The strata are roughly conformable and dip 10° to 15° to the eastward. The lowest bed visible in the section exposed appeared to correspond to layer No. 6 of the section.

The fossiliferous layer here contained *Ostrea veatchii*, *O. tayloriana*, *Crepidula prærupta*, Galerus, Pecten, Modiola, Modiolaria, Drillia?, and Chrysodomus, all rather scarce except the oysters. The latter were frequently bored by Cliona. The fossils were generally fairly well preserved, and mixed with fragments of silicified or carbonaceous vegetable matter in the matrix of more or less argillaceous sandstone. A cetacean vertebra was also found.

PENINSULA OF ALASKA.

It can hardly be doubted that these strata reappear on the peninsula north of Shumagin Islands, as the Kenai beds do. Grewingk speaks (Geogn. Palaeont. Bemerk. p. 58, footnote) of their existence on the shores of Portage Bay and at Port Möller, while at other points on the north shore of the peninsula in that vicinity Postels[1] speaks of horizontal fossiliferous strata carrying many bivalve shells, reaching a thickness above the sea level of 300 feet. These are doubtless of the same age as the Crepidula bed of the Shumagin Islands. At Pavloff Bay, both on the flanks of the Pavloff Volcano and near the settlement, Wossnessenski obtained a large number of fossil valves belonging to this fauna.

[1] Lütké, Voy. Séniavine, vol. 3, p. 27.

WALRUS BAY.

On Morzhowi or Walrus Bay, in the first bluff eastward from Sannakh Strait (or Isanotski Strait, as it is also called), at 50 toises above the level of the sea, lies a horizontal bed containing the same species of fossil bivalves previously noted at Pavloff Bay. This layer is covered by about 50 toises more of sand and clay. The same layer is noted by Lütké (Partie nautique, p. 272) on the west shore of Cold Bay.[1]

UNALASKA.

On the island of Unalaska, at the north-northwestern foot of the volcano of Makushin, the same beds occur again, and from them their characteristic fossils have been collected by Wossnessenski, Kastalski, and Dr. Stein.[2] They are also reported to exist in one of the bays near Chernoffski, in the western part of the island.

ATKA.

The most western point where these beds have been recognized in the Aleutian chain is on the western side of the island of Atka, on a small inlet known as Sand Bay, which extends from the northern part of Korovinski Bay. Here the beds are near the sea level, but near by, on the western slope of Konushi Volcano, they appear at an elevation of about 30 feet and consist of hard argillaceous and indurated sandy layers with the usual fossil bivalve shells.

NUSHAGAK.

Proceeding northward along the mainland, at the head of Bristol Bay the Nushagak River enters an inlet some miles in extent. At the head of ship navigation is the location of the Russian trading post of other days called Fort Alexander. On the shore of the river in this vicinity, but of which we have no more precise information, a small collection of fossils in an indurated clayey matrix was obtained by the late C. W. McKay. They agree in every respect with those from the Pribilof Islands, and add some species to our list. The presence of these beds at this place is therefore definitely established, but nothing is known of their extent.

ST. PAUL ISLAND.

Nearly due west from Bristol Bay, in the midst of Bering Sea, rises the Pribilof group of islands, celebrated for their fur-seal fisheries. The settlement on St. Paul Island is situated on the neck of a small peninsula, on either side of which is a stretch of sand beach bounded by crags of basaltic rock and lava. On the east side of this peninsula,

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[1] Cf. Veniaminoff, vol. 1, pp. 222 and 236.

[2] Grewingk, op. cit., p. 123; Trudi, Mineral. obst., St. Peterburg, 1830, pp. 382–383.

which forms the southeastern extreme of the island, is a bluff or crag known as Black Bluff, which, according to the observations of Wossnessenski in 1847–48, is composed of horizontal layers of a hard claystone, with others in which lime preponderates, forming a pale-gray, fine-grained, clayey limestone, or in which a conglomerate of pebbles of volcanic origin is bound together in a limy matrix.[1] Over these are layers of black or brown volcanic breccia and vesicular lava. These bluffs rise abruptly to a height of 60 to 80 feet above the sea at their base. From the limestone and argillite marine fossils have been obtained by Wossnessenski, Elliott, Dall, W. Palmer, and C. H. Townsend, of which a collection exists in the National Museum, enumerated in the preceding table. About twenty-eight species are known from this locality, which is stated to be the only spot in the whole group where any fossiliferous rocks occur,[2] the remainder of the islands being composed of volcanic rocks and alluvium of very recent origin.

Observations made in 1891 by Mr. J. Stanley-Brown,[3] special agent of the Treasury Department, convinced him that at present no distinct trace of any limy stratum is perceptible in the Black Bluff. The fossils obtained by him were contained in rounded, apparently waterworn pebbles, which were indiscriminately included in a general mass of volcanic ashes and other eruptive matter of which the bluff is formed. No extinct species appeared in the collection brought back by Mr. Stanley-Brown, while several are noted from the material of the earlier collections. It would seem possible that pebbles of more than one geological epoch may be included in the mass, or that the wear of the waves for half a century has cut away enough of the bluff to hide or destroy the limy stratum referred to by Grewingk, and which may have been of limited extent. It is certain that, from an examination solely of the material collected in 1891, the fossils might be referred to an age as late as the post-Pliocene, which would not agree very well with the fauna reported by Grewingk and others. The fossils collected by Mr. Stanley-Brown and not included in the earlier collections are as follows: *Buccinum tenue* Gray?, *B. polare* Gray?, *Admete couthouyi* Jay?, *Leda* sp., *Yoldia limatula* Say, *Lepton grande* Dall, *Cardium islandicum* (very abundant), *Macoma sabulosa* Spengler, and a fragment possibly of a Panopea. All these occur living at moderate depths in the Bering Sea, immediately adjacent to the island, at present. Owing to the doubt as to their age, they have not been included in the table of fossils of the Astoria group heretofore given.

This deposit has been discussed by Dr. George M. Dawson,[4] who corroborates Mr. Stanley-Brown's description of the conditions under which the fossils are found, but regards them as having been detached from the sea bottom by a volcanic eruption, with the products of which

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[1] Grewingk, Beitrag p. 190.
[2] Cf. H. W. Elliott, Condition of Affairs in Alaska, 1875, p. 70.
[3] Bull. Geol. Soc. America, Vol. III, 1892, p. 496.
[4] Bull. Geol. Soc. America, Vol. V, 1895, pp. 130–132.

they were mixed, and therefore does not consider them as fixing the age of the formation in which they occur, but only as representing beds already in existence at the time of the eruption.

COMMANDER ISLANDS.

On the Commander Islands, west of the Aleutians, rocks of the same age probably occur, since on Bering Island Stejneger collected some specimens of a conglomerated hard gravel of highly polished pebbles united by a limy cement, containing fragments of bivalves (Saxicava?) and a single piece of claystone with the imprint of a bivalve not yet identified.

OTHER LOCALITIES.

The islands northward from the Pribilof group do not appear to contain fossiliferous strata. St. Matthew and its adjacent islets are composed of porphyritic, granitic, and volcanic rocks.

While at anchor off Pinnacle Island in 1880, when the vessel was situated so that the central gash or fissure between the lateral crests was in profile, a distinct glow arising from this fissure was observed at night by our party. This led to the supposition that the island was a volcanic chimney, and I have been told by navigators familiar with these seas that they had observed smoke arising from the V-shaped crevice alluded to. But Dr. Dawson,[1] who circumnavigated the island on a steam launch, is of the opinion that this view is incorrect. He regards the rocks as belonging to an old volcanic series similar to those of Cape Upright. Some beds of gray arkose material like that of Cape Upright are reported by him as consolidated into a hard rock, but occasionally showing distinct stratification.

St. Lawrence is chiefly gray biotite-granite, though slate is reported to exist at its southeastern extreme. The island as a whole is composed of reddish granitic domes overlain by volcanic rock and united by stretches of débris, due to weathering alluvium and sea sand. The Diomedes are massive domes of a white or grayish syenite. The statement of Muir[2] that they have been glaciated is without foundation in fact, and the same may be said of other islands to the south.

Returning to the mainland, the last area in which rocks of the Astoria group are known to occur is that of the Nulato sandstones on the Yukon River between Kaltag and the Koyukuk Mountain. These have already been described in connection with the Kenai beds of the same region, and it seems unnecessary to recapitulate the data here.

It may be added here that there is reason to believe, notwithstanding the imperfect data which are on record, that the Kenai group and the Astoria group are both represented by analogous beds on the southern

[1] Bull. Geol. Soc. America, Vol. V, 1894, p. 138.

[2] Cruise of the *Corwin* in 1881, Washington, Treasury Dept., 1884, 4°, 147 pp. Treasury Dept. Doc. No. 601; see pp. 140–142. See also Dawson, op. cit., pp. 139–140, 1894.

part of the peninsula of Kamchatka and on the northern shores of the Japanese island of Yesso, though the discussion of those exotic localities is outside of the limits of this essay.

PLIOCENE BEDS OF MARINE ORIGIN.

Identifiable Pliocene appears to be remarkably rare north of California. The small patch noted by Dr. Condon at Shoalwater Bay, Washington, lying conformably between beds of marine Miocene and Pleistocene, appears to be the only locality for many miles. In common with the more extended beds in California, its fauna indicates a colder water temperature than at present, and contains a large proportion of species which have since receded northward some hundreds of miles at least and now find a congenial habitat in the Aleutian chain and Sitkan archipelago.

ST. ELIAS ALPS.

In his geological researches on the St. Elias Alps and the region westward from the Yakutat Bay, Mr. I. C. Russell[1] has discovered fossiliferous rocks elevated to 5,000 feet above the sea, containing fossils which all belong to recent species, yet which, since they belong to a more northern fauna than at present is known to inhabit that locality, are probably referable to the Pliocene rather than the Pleistocene, a view which is to some extent supported by the enormous elevation to which they have been subjected. Our ideas of what shall constitute Pliocene on the Pacific Coast are still rather vague, and may be said to involve the idea of a marine fauna containing a certain proportion of extinct species. Hereafter we may be better able to define the period in terms of dynamic geology, but at present both the recent and fossil faunas are but approximately known, and all determinations of the age must be taken as provisional. It can not be safely assumed that either the supposed Pliocene or the Glacial and post-Glacial epochs on the Pacific Coast were wholly synchronous with those periods on the Atlantic Coast to which the same appellations have been assigned. We may, however, be not far wrong in assuming that the Pliocene epoch was intimately associated with those great movements of elevation which have been more or less definitely recognized along the whole Pacific Coast from California northward.

THE GROUND ICE FORMATION.

A remarkable formation has been recognized in many places in the northern part of Alaska, in which solid beds of ice of considerable thickness perform the functions of rock strata and are covered by beds of blue clay containing numerous remains of Pleistocene mammals, or by beds of alluvium which sustain a layer of turf, with ordinary profuse

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[1] Nat. Geog. Mag., Vol. III, 1892, pp. 171–172.

herbage of the region, or even small thickets of birch, alder, and other small Arctic trees.

ESCHSCHOLTZ BAY ICE CLIFFS.

This formation was first noticed by Kotzebue, during his exploration of the sound which bears his name, in the year 1816.[1] The remains of animals which were associated with the clays above the ice were described in his appendix on the natural history by Eschscholtz.[2] The locality at which the original discovery was made is known as Elephant Point, Eschscholtz Bay, the bay being an arm of Kotzebue Sound.

This locality was visited by H. M. S. *Blossom*, Capt. F. W. Beechey, in 1826,[3] and observations on the ice formation were made by Surgeon Collie, of the expedition, which, with the vertebrate remains collected, were discussed by Dean Buckland in the appendix to the narrative of the voyage. Kotzebue and Eschscholtz correctly described the formation as interbedded ice. Beechey's party, deceived by the mantle of clay which at the time of their visit had fallen so as to mask the main body of the ice face, concluded that the ice was a superficial deposit. They noted similar deposits of clay more or less associated with ice at numerous other points on the Arctic coast.

In 1848 Captain Kellett, in H. M. S. *Herald*, accompanied by Berthold Seemann and Dr. Goodridge, visited Kotzebue Sound and Elephant Point with the narratives of Kotzebue and Beechey in their hands, and fully confirmed the views expressed by Kotzebue and Eschscholtz as to the interstratified position of the ice and the relation to it of the bone-bearing clay. Their results were subsequently discussed at length by Edward Forbes and Sir John Richardson.[4] The fossil mammals were fully described and illustrated in their publication.

In 1880, when commanding the United States Coast Survey cutter *Yukon*, I visited Kotzebue Sound, and carefully examined this classic locality. My report was subsequently printed by direction of the Superintendent of the Survey.[5] As these notes give the fullest account of this formation at its typical locality they will be cited verbatim:

> We landed at a small low point [on the south shore of Eschscholtz Bay, west from Elephant Point][6] near some old huts and proceeded along the beach for about a mile, the banks being chiefly composed of volcanic breccia or a slaty gneissoid rock. They rose 15 to 50 feet above the sea, rising inland to hilly slopes without peaks, and probably not attaining more than 300 or 400 feet anywhere in the vicinity.

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[1] Kotzebue, Voyage of Discovery into the South Sea and Beering's Straits, London, Longmans, 1821, 3 v., 8°, vol. 1, p. 220.

[2] Op. cit., vol. 3.

[3] Narrative of a Voyage to the Pacific and Beering's Strait, by F. W. Beechey, R. N., London, Colburn & Bentley, 1831, 742 pp., 4°. Cf. part 1, pp. 257–259; and for Buckland's discussion, see appendix to the same, pp. 593–612. Also, Zoology of Captain Beechey's Voyage, London, H. G. Bohn, 1839, 180 pp., 4°, 46 pl. For Collie's geological notes on the ice cliffs, see Geology, pp. 169–173, and Pl. I.

[4] Zoology of the voyage of the *Herald*, edited by Edward Forbes; Vertebrals by Sir John Richardson, London, Lovell Reeve, 1854, 171 pp., 4°, 33 pl.

[5] Notes on the vicinity of Bering Strait: Am. Jour. Sci., vol. 21, 1881, pp. 104–111.

[6] Phrases inclosed in brackets are now added for clearness.

As we passed eastward along the beach a change took place in the character of the banks. They became lower and the rise inland was less. From reddish volcanic rock they changed to a grayish clay, containing much vegetable matter, which in some places was in strata in the clay and in others indiscriminately mixed with it. Near the beginning of these clay banks, where they were quite low, not rising over 20 feet above the shore, we noticed one layer of sphagnum (bog moss) containing fresh-water shells belonging to the genera Pisidium, Valvata, etc. This layer was about 6 inches thick. The clay was of a very tough consistency, and though wet did not stick to or yield much under our feet. The sea breaks against the foot of these banks and undermines them, causing them to fall down, and the rough, irregular talus that results is mingled with turf and bushes from the surface above. A little farther on a perpendicular surface of ice was noticed in the face of the bank. It appeared to be solid and free from mixture of soil except on the outside. The banks continued to increase slowly, but regularly, in height as we passed eastward. A little farther on another ice face presented itself on a larger scale. This continues about 2½ miles to Elephant Point, where the high land turns abruptly to the south and west, and we followed it no farther. The point itself is boggy and low, and is continued from the foot of the high land, perhaps half a mile to the eastward, forming the northwest headland to a shallow bay of considerable extent.

To return to the "cliffs." These, for a considerable distance, were double; that is, there was an ice face exposed near the beach with a small talus in front of it and covered with a coating of soil 2 or 3 feet thick, on which luxuriant vegetation was growing. All this might be 30 feet high. On climbing to the brow of the bank the rise from that brow proved to be broken, hummocky, and full of crevices and holes; in fact, a second talus on a larger scale ascending to a second ice face, above which was a layer of soil 1 to 3 feet thick covered with herbage.

The brow of this second bluff we estimated at 80 feet or more above the sea. Thence the land rose slowly and gradually to a rounded ridge, reaching the height of 200 or 300 feet only at a distance of several miles from the sea, with its axis in a north and south direction, a low valley west from it, the shallow bay at Elephant Point east from it, and its northern end abutting in the cliffs above described on the southern shore of Eschscholtz Bay. There were no mountains or other high land about this ridge in any direction; all the surface around was lower than the ridge itself.

About half a mile from the sea, on the highest part of the ridge, perhaps 250 feet above high-water mark, at a depth of a foot we came to a solidly frozen stratum, consisting chiefly of bog moss and vegetable mold, but containing good-sized lumps of clear ice. There seemed no reason to doubt that an extension of the digging would have brought us to solid, clear ice, such as was visible at the face of the bluff below; that is to say, it appeared that the ridge itself, 2 miles wide and 250 feet high, was chiefly composed of solid ice overlain with clay and vegetable mold. It was noticeable that there was much less clay over the top of the upper face than was visible over the lower one, or over the single face when there was but one, and the land and the bluff were low near the beach. There also seemed to be less vegetable matter. Near the beach 6 or 8 feet of clay were observed in some places, without counting what might be considered as talus matter from farther up the hillside. In one place only did we notice a little fine, reddish gravel, and nowhere in the talus or strata any stones.

The ice face near the beach was not uniform. In many places it was covered with clay to the water's edge. In others, where the bank was less than 10 feet high, the turf has been bent without breaking after being undermined, and presented a mossy and herbaceous front, curving over quite to high-water mark.

The ice in general had a semistratified appearance, as if it still retained the horizontal plane in which it originally congealed. The surface was always soiled by dirty water from the earth above. This dirt was, however, merely superficial. The outer inch or two of the ice seemed granular, like compacted hail, and was sometimes whitish. The inside was solid and transparent, or slightly yellow tinged, like peat water, but never greenish or bluish like glacier ice. But in many places the ice presented the aspect of immense cakes or fragments, irregularly disposed, over which it appeared as if the clay, etc., had been deposited. Small pinnacles of ice ran up into the clay in some places, and above holes were seen in the face of the clay bank where it looked as if a detached fragment of ice had been and had been melted out, leaving its mold in the clay quite perfect.

In other places the ice was penetrated with deep holes, into which the clay and vegetable matter had been deposited in layers, and which (the ice melting away from around them) appeared as clay and muck cylinders on the ice face. Large rounded holes or excavations of irregular form had evidently existed on the top of the ice before the clay, etc., had been deposited. These were usually filled with a finer grained deposit of clay, with less vegetable matter, and the layers were waved, as if the deposit had been affected by current action.

In these places especially was noticed the most unexpected fact connected with the whole formation, namely, a strong, peculiar smell, as of rotting animal matter, burned leather, and stable manure combined. The odor was not confined to the spots above mentioned, and was not quite the same in all places, but had the same general character wherever it was noticed.[1] A large part of the clay had no particular smell. At the places where the odor was strongest it was observed to emanate particularly from darker, pasty spots in the clay (though permeating elsewhere), leading to the supposition that these might be remains of the soft parts of the mammoth and other animals, whose bones are daily washed out by the sea from the clay talus.

At or near these spots, where the odor was strongest, a rusty, red lichen, or lichen-like fungus, grew on the wet clay of the talus in extensive patches. Some of these, a sample of the bad-smelling deposit, and as many bones of the mammoth, fossil buffalo, etc., as we could carry were secured. These included a mammoth tusk with both ends gone, but still 5½ feet long and 6 inches in diameter. Dwarf birches, alders 7 or 8 feet high, with stems 3 inches in diameter, and a luxuriant growth of herbage, including numerous very toothsome berries, grew with the roots less than a foot from perpetual solid ice.

The formation of the surrounding country shows no high land or rocky hills from which a glacier might have been derived and then covered with debris from their sides. The continuity of the mossy surface shows that the ice must be quite destitute of motion, and the circumstances appear to point to one conclusion—that there is here a ridge of solid ice, rising several hundred feet above the sea, and higher than any of the land about it, and older than the mammoth and fossil horse, this ice taking upon itself the functions of a regular stratified rock. * * * Though many facts may remain to be investigated, and whatever be the conclusions as to its origin and mode of preservation, this formation certainly remains one of the most wonderful and puzzling geological phenomena in existence.

From the character of some of the bad-smelling deposit which was brought home and appeared to be composed exclusively of vegetable fiber finely comminuted, no doubt is felt that it represents dung of the mammoth or some other herbivorous animal which had been preserved in pockets on the surface of the ice where it was probably dropped,

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[1] This phenomenon was observed by Kotzebue, Beechey, and the *Herald* party, and lends further probability to the view that the animals were mired in the clay and thus met their death. Since, if the clay contained merely the accumulated bones of animals which had died and decayed on the surface of the ground, it is unlikely that so much animal matter would have been hermetically sealed in the clay and kept on ice to offend the nostrils of later visitors. On the other hand, if the ice had not been present and the temperature not kept so low it is unlikely that, even in the clay, animal matter could have been preserved for such an enormous period of time in a condition to give out so ammoniacal a stench. All the circumstances point toward the view that the ice preceded and subsequently coexisted with animals whose remains are now found in its vicinity.

and by its dark color attracting the rays of the sun had sunk in, as is usual with dark objects dropped on an exposed ice surface. It may be reiterated that the bones, as noted by previous observers, are contained in the clay above the ice; never in the ice itself. They are exposed by the melting away of the ice face and the consequent fall of the superincumbent clay, which is afterwards disintegrated by the action of the waves, leaving the bones exposed on the broad, flat, muddy beach. The remarkably fresh appearance of the bones is amply accounted for by the low temperature and dense character of the clay in which they are embedded, in which the animals may have become mired and so perished.

The report of Dr. Goodridge, which appears to have been prepared with great detail, was unfortunately not printed. In some extracts from it given by Richardson it is stated that at one of the ice cliffs a section was exposed showing 50 feet of pure, clear ice above, and behind it layers of drifted material, peat, covered with a thick bed of broken sticks and vegetable matter, over which lay a stratum of red river gravel, upon which was a bed of argillaceous earth capped by dry, friable mold and surface peat, with the usual turf and herbage. The sticks were larger than any growing in the vicinity, but they may have been drifted from the wooded region of the interior. At another place the ice wall was 80 feet high. E. W. Nelson, who visited this locality in 1881 with the U. S. S. *Corwin*, also observed such an accumulation of sticks, and noted that some of them had been gnawed by beavers. The following list of species is mainly extracted from Richardson's report, those marked with an asterisk having been obtained by me in 1880. The nomenclature has been somewhat modernized.

* Elephas primigenius Blumenbach.
Elephas columbi Falconer (?).
Equus major De Kay.
Alces americanus Jardine = machlis Ogilby.
* Rangifer caribou Baird.
* Ovibos moschatus Blainville.
* Ovibos maximus Richardson = O. cavifrons Leidy.
* Bison crassicornis Rich. = B. antiquus Leidy.

Analogous beds of clay, sometimes with vertebrate remains, were observed by Beechey's party at the following localities:[1]

On the north shore of Eschscholtz Bay and also on the west from it; on the south shore of Spafarieff Inlet and Good Hope Bay; at Shishmaref Inlet, west-southwest from Cape Spanberg; at Cape Blossom; northward from Kotzebue Sound, at Point Hope; at various points between Cape Beaufort and a point 20 miles east from Icy Cape; and near Point Belcher, in north latitude 71°.

From information gathered from several masters of vessels in the whaling fleet and derived from experience gained in the effort to dig graves for seamen who had died aboard vessels on this shore from time to time during the last twenty years, it would appear that somewhat

[1] Op. cit., p. 603.

north of Cape Beaufort the land between the low hills and the sea is low and the soil chiefly a sort of gravel. "At a depth of 2 feet is a stratum of pure ice (not frozen soil) of unknown depth. This formation extends, with occasional gaps, north to Point Barrow, and thence east to Return Reef, where the ice layer is about 6 feet above the level of the sea. It goes south at least as far as Icy Cape without any decided break, and is found in different localities as far south as Kotzebue Sound." At Point Barrow, near the international station, under the direction of Lieut. P. H. Ray, United States Army,[1] a shaft was sunk to a depth of 37 feet 6 inches, which passed through successive layers of mud, sand, and fine gravel, with fragments of driftwood and marine shells, showing here and there large fragments of pure fresh-water ice, but no continuous stratum of ice. The formation here was clearly a beach alluvium, and relatively modern, a pair of Eskimo wooden snow goggles with a sinew string still attached to them being found at a depth of 27½ feet. The temperature of the earth varied from $-5°$ to $+17.5°$ F.; below the influence of the external air the temperature of the earth was quite steady at 12° F. for nine months. The earth was frozen and was extremely hard and tough. Blasts put into the side of the shaft blew out without shattering the frozen earth around the drill hole. It is probable that excavations farther inland might have revealed the ice layer, which at the locality of the station did not exist.

KOWAK RIVER ICE CLIFFS.

After that at Elephant Point, the most remarkable exhibition of the Ground ice formation which has yet been recognized is situated on the lower part of the Kowak River, which empties into Hotham Inlet. The cliffs are situated along the bends of the river, which is extremely tortuous, almost exactly due north from Elephant Point, near where a line drawn from Elephant Point to Deviation Peak cuts the Kowak River. They have been illustrated and briefly referred to by Lieut. John C. Cantwell,[2] United States Revenue Marine, who discovered them in 1884 and revisited them the following year. They are composed of solid ice, covered by a layer of dark-colored earth, uniformly about 6 feet thick, the whole rising to the height of 15 to 150 feet, with trees 4 to 8 inches in diameter growing on the surface. Up to this point, and for some distance farther, not a stone or pebble was to be seen, the bluffs along the river appearing to be composed of clay or soft earth, which fell in large masses where undermined by the river.

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[1] Report of the International Polar Expedition to Point Barrow, Alaska. Washington. House Ex. Doc. No. 44, 48th Cong., 2d sess., 1885, 4°; cf. pp. 24, 338–339.

[2] Report on the cruise of the *Corwin* in the year 1885, by Capt. M. A. Healy, United States Revenue Marine. Washington. House Ex. Doc. No. 153, 49th Cong., 1st sess., 1887; cf. Lieutenant Cantwell's Report, pp. 48–49. Also Science, Dec. 19, 1884, vol. 4, No. 98, pp. 539, 551–554; Jan. 30, 1885, vol. 5, No. 104, pp. 92–93; and Oct. 30, 1885, vol. 6, No. 143, p. 380.

See also Russell (I. C.), Ice Cliffs on Kowak River, Alaska: Am. Geologist, July, 1890, vol. 6, No. 1, pp. 49–50, and letter of Lieutenant Cantwell, following, pp. 51–52.

THE KOWAK CLAYS.

At a point on the river in about west longitude 158° a remarkable clay bluff, three-fourths of a mile long and 150 feet high, was reached on the left bank of the river. Quantities of mammoth tusks were observed in this clay and its débris, where undermined by the stream. These clays were doubtless of the same age as those in which the mammoth remains are found at Elephant Point over the ice cliffs. Their position is significant, being near the lower end of a tract of open tundra, below the low divides leading northward to the Noatak River and southward to the Selawik Basin, and near where the Kowak River enters a defile which later becomes a sort of canyon obstructed by rapids.

Returning to the ice cliffs, during the explorations of 1885 it was observed that "for miles along the river in this portion of its course these icy cliffs appear and disappear at regular intervals, so that they recur in bends that are parallel with each other." An east-northeast and west-southwest magnetic line drawn through one of the cliffs if prolonged will cut all the others as well as the analogous formation at Elephant Point far to the southward. "Climbing to the top of one of these ice cliffs" Messrs. Cantwell and Townsend pushed their way "through the dense thickets of willow and luxuriant growth of grass into the interior for about 1 mile, where we found a shallow lake about a mile in diameter." If the travelers stood still on the peaty soil for any length of time "the spongy moss became saturated and soon a pool of dark-colored water made our position untenable" (op. cit., pp. 48–49). The formation does not extend to the Noatak River, which was explored by McLenegan in 1885.

For these clays, whether independently deposited or found superposed on the Ground ice formation, the name of the Kowak clays was suggested by me in 1892.

DISTRIBUTION OF FOSSIL VERTEBRATES.

Other Alaskan localities for the animals associated with the clays are the Kotlo River, a stream entering the Yukon from the south above old Fort Yukon and close to the Arctic circle; the valley of the Inglutalik River, which empties into Norton Bay, and of the Ulukak River, which enters Norton Sound at Unalaklik. A lake near Nushagak is stated on Russian authority to afford an abundance of similar bones. They are reported from the upper part of the Knik or Fire River, which debouches into Cook Inlet; and on the Arctic coast, in latitude 71°, at a point called Skull Cliff, Beechey's party obtained remains of an elephant in a clay overlying a low stratum of ice. Wossnessenski collected tusks, teeth, and bones of *Elephas primigenius* and *E. columbi* near Topanika Creek, Norton Sound. Other remains of the same sort have been picked up on the coast between Bristol Bay and Norton Sound. Teeth of the elephant, bones of *Bison antiquus*, and especially of the musk ox, are not rare on the tundra of the Yukon Valley, whence specimens were brought by me in 1868. But the Kotlo and Inglutalik rivers have the reputation of affording these bones in extraordinary numbers. Along the Arctic coast, east from Point Barrow, where the bones and ivory occur frozen into the clays, they are so common as to serve the Eskimo carvers for economic purposes. I obtained in 1880 a deep ladle, as large as a child's head, carved, handle and all, out of a solid tusk of mammoth ivory by these people. It was said to have come from the mouth of the Colville River.

NAKNEK RIVER, AND REMAINS OF THE MAMMOTH.

The latest contribution to our knowledge of the distribution of the Ground ice and clays with mammoth remains was obtained during our trip of 1895. They appear to be represented in the river deltas of the northern coast of the peninsula of Alaska. Here, near the mouth of the Naknek River, the existence of the ice covered by heavy banks of clay is reported by several of the traders doing business in that vicinity. The place was visited by Mr. W. J. Fisher, an old collaborator of the Smithsonian Institution, on board one of the trading vessels, in the spring of 1894. The freshets had melted the icy layer and cut away the clays until, by a fall of part of the bank, remains of the mammoth were exposed in a cavity in the frozen clay. The spot was visited by the natives of an adjacent Eskimo village, who obtained mammoth bones and a large quantity of fat, which they used in greasing their skin boats. The quantity is estimated at 300 pounds. Mr. Fisher reports that when he arrived there and was informed of the find, the cavity in the frozen clay still retained something of the form of the mammoth, and underneath the organic débris, bones, etc., at the bottom he obtained a piece of the fat in good preservation. This was presented by him to the writer for the United States National Museum, where it is now preserved. It has the consistency of hard tallow, and still contains numerous dried muscular fibers. It would seem that the carcass had been more or less demoralized before it was embedded in the clay, as no mention was made by the natives of any skin or hair in connection with the remains, only of disintegrated muscular tissue, bones, and fat. As mammoth bones have no particular value in that part of the world, where transportation of the most necessary articles is always a matter of difficulty, no attempt was made by the natives or Mr. Fisher to bring away any of the bones, a large part of which had fallen into the river. There can be no question whatever of the accuracy of the identification of the remains with those of the mammoth, which are well known to both Mr. Fisher and the natives.[1]

[1] See Science, Nov. 8, 1895, p. 636.

It is a question whether this occurrence does not throw light on the finding of mammoth teeth and bones on the Pribilof and Aleutian islands. The freshets always occur before the sea ice goes out, and such remains frozen in the drifting floe might easily be carried before one of the spring gales to the shores of adjacent islands. It is known that erratics and occasional articles of native manufacture of continental origin have been so transported to the islands, and there seems to be no particular reason why mammoth remains should not share the same fate now and then.

OTHER LOCALITIES.

I close this summary by a reference to the discoveries of a mammoth tooth on the island of St. George, of the Pribilof group, in 1836, vouched for by Veniaminoff (Unal. I, p. 106), and of tusks and teeth on the island of Unalaska in 1801, according to the report of Dr. Stein.[1] The Ground ice formation and the Kowak clays have been considered here for several reasons. Though the former may be correlated with the Glacial epoch of cold and the latter with the post-Glacial era, yet there are certain reasons why this, even if probable, is not inevitable.

ORIGIN OF THE ICE AND CLAY.

In our ignorance of the chronology of the Alaskan geology it is well to consider alternatives. The fact that the Californian marine Pliocene indicates a colder sea than do the invertebrates of the Pleistocene, and that this is confirmed by the evidence of the Oregon and Yakutat fossils, which we have called Pliocene in this essay, has been already alluded to. It is quite certain that an elevation of the shores of Bering Sea and the continental shelf lying off them if carried to 200 feet would unite Asia and America; if to 300 feet, would connect the eastern Aleutians as far as Umnak and the Pribilof Islands with America, and would lay bare an enormous level plain covering the northern half and most of the eastern third of the present area of Bering Sea. The diminished body of water which would be left in such a case, in connection with the prevalence of the northwest trade winds over this area, would give to this region such a dry climate as characterizes much of Siberia and the Yukon Valley in Alaska. If the elevation took place at the end of the Miocene, as it did in California and Oregon, and as the location and condition of the Nulato sandstones suggest, and if the greatest elevation was toward the west and gradually diminished eastward, we should have conditions favorable for the following results: First, a small precipitation with little snow, which with extreme cold and an almost level surface would be unfavorable to the formation of glaciers. Second, the formation, by the drainage of the Yukon and other streams coming down from

[1] Trudi mineral. Obst., St. Petersburg, 1830, pp. 382, 383.

the east, of vast shallow lakes of muddy water, the remnants of which in winter, after the escape of the surplus water, might, as now occurs in the same region, freeze solidly to the bottom and receive considerable additions from the snows of winter. Third, the ice thus formed might to a certain extent persist, especially if protected from the sun of the short Arctic summer by a deposit of clay from the spring freshets. Fourth, with a return of a milder climate, though the great mass of this ice might melt and escape with the drainage, that in the more northern and colder region, especially where protected by the clays, might be to some extent conserved and over the clay bogs above it a carpet of Arctic vegetation might gradually extend.

The wandering vertebrates, attracted by the luxuriant herbage which we know to flourish in such places, might be trapped in the quagmires which the grasses treacherously conceal. Further elevation by affording better drainage would tend to preserve rather than to waste the hidden stores of ice, while the rivers gradually cutting down their channels would expose the formation when it lay along their path.

That the moderate elevations which exist in the region were insufficient to start into motion the ice thus formed, and thus inaugurate glaciers, may be accounted for on several grounds. First, under the assumed circumstances the ice would always be formed on the lowest places of the level lowlands, coming there as water, and not as snow pressing from slopes. Second, the ice under conditions of very low temperature is, without doubt, much more rigid than at higher temperatures, and by the hypothesis would more or less thoroughly be incorporated at its base with the tough and rigid frozen mud upon which it formed; in fact, the ice and soil would practically form one body, while ice formed from snow falling on frozen earth would always behave more like a body extraneous to the soil. Lastly, the very level character of the region would be unfavorable to motion in the ice, as at present on the Arctic coast where we know the land ice is stationary; while in particular localities, where some motion might take place, the character of the Miocene sandstones, upon which most of it must have rested in the absence of alluvium, is not well suited to retain any evidence of it.

These suggestions are offered as a basis for discussion in considering the anomalous geological conditions of northwestern Alaska, until a greater knowledge of the facts may afford a foundation for some more applicable hypothesis.

Owing to the crystalline character of the ice as observed by me at Kotzebue Sound, Mr. Warren Upham has thought to recognize in it true glacial ice.[1] This, however, is too hasty an inference. All ice derived from snow by pressure of its own or other weight has this structure, including glacier ice. But ice without motion, past or actual, can not properly be regarded as glacial, no matter from what conditions

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[1] Am. Geologist, Vol. XV, No. 4, April, 1893, pp. 251–259.

it has been derived. The Kotzebue Sound ice is undoubtedly snow ice, but we have as yet no proof whatever of its glacial origin. I have thought that some of the Ground ice seen by me was stratified, showing alternating layers of granular and solid ice, to be accounted for as above stated, but in the multiplicity of duties laid upon me during field work in past years I have failed to find time to properly investigate the minor details of the question and can not affirm that the impression was based on sufficient evidence.

Dr. Dawson has discussed the occurrence of mammoth remains in Alaska,[1] taking a view of its origin not dissimilar to that above suggested, but observing that nothing has been adduced to show that it is absolutely continuous over any great area. This must be admitted, and indeed it is difficult to imagine conditions under which any great area of ice could have been preserved in the manner supposed. Nevertheless, it remains true that in favorable situations about the whole eastern shore of Bering Sea and Strait and, according to the reports of whalers and explorers, along a great part of the Arctic coast of Alaska considerable areas exist where the Ground ice is preserved. In this connection reference may be made to a paper on snowdrift deposits by Charles Davison,[2] which contains data bearing on the general topic.

NOTES ON THE YUKON VALLEY.[3]

In the Yukon Valley the Astoria series overlies the Kenai series, with which it is strictly conformable, both dipping to the northwest from 10° to 40°. The rock is a coarse grayish-brown sandstone, containing casts of Ostrea, Macoma, and other marine bivalves, besides fucoid remains. It extends from Koyukuk to Kaltag, along the Yukon, a good exposure of some 60 feet being afforded by the erosion of the banks, the thickness determined for the beds being at least 300 feet; the strata are very regularly waved and occasionally broken, the waves varying from a mile and a half to a quarter of a mile in length.

The Yukon flows through a country diversified by rolling hills of low altitude, seldom exceeding 1,500 feet. The bed of the river is on the right side of a valley or depression of variable width, but from Nūklūkahyét to the great southern bend the right bank is the higher, and the left bank is more or less composed of alluvium, which stretches usually for some distance to rather low hills. There are no terraces. An account of the character and method of formation of the alluvium will be found in the Proceedings of the Boston Society of Natural History, Volume XIII, 1869, page 138.

To the north of the Porcupine River, where it enters the Territory, are low hills. These soon pass into an open plain, very low and marshy,

[1] Quart. Jour. Geol. Soc. London, vol. 50, 1894; pp. 1–9 of separate copy.
[2] Quart. Jour. Geol. Soc. London, vol. 50, Aug., 1894, pp. 472–486.
[3] These notes are from unpublished observations made by W. H. Dall in 1866–1869.

sparsely wooded with a light growth of spruce, willow, birch, alder, etc. At the farthest extremity of this plain, northward, are the Romanzoff Mountains, the only snow-bearing peaks in summer in this part of the Territory. Their position and trend were determined by bearings from different points on the river. The accounts of the voyagers who have visited that part of the Territory unite in the statement that these mountains are mostly composed of metamorphic schists and quartzose rocks. North of them, according to the same authority, a low plain or tundra extends to a low range of hills which border the Arctic coast. The Romanzoff chain appears to end rather abruptly to the southwest, but in the same trend a line of low, broken hills continues toward the headwaters of the Dall River, a stream of some magnitude flowing from the north, and named by Captain Ketchum, the first of our pioneers to ascend the Yukon, and an efficient coadjutor in the work of exploration. This river brings down nothing but fragments of metamorphic argillites and quartz rocks, which are evidently derived from the high, rocky hills at the base of which it flows.

On the south side of this plain a similar but less elevated series of hills (of similar rocks) converge toward the Yukon, so that that river, near the mouth of the Dall River, enters a narrow funnel of hills which approach each other until a canyon is formed, through which the great Yukon surges and boils in a narrow but exceedingly deep channel. These rocks, which rise to the height of 1,500 or 2,000 feet on each side of the river, cutting off a great portion of the daylight, are all metamorphic, and most of them are very greatly altered. They vary from schistose to argillitic, from jasper to trachytic, but are mostly very hard and flinty, traversed with numerous quartz veins containing a small amount of iron pyrites; but no trap dikes were noticed nor any fossiliferous rocks of any kind. The canyon varies from one-half to one-fourth of a mile in width, and the rise of the water in the spring freshets, as indicated by the scoring and smoothing of the rocks, is about 30 feet, while a fall of 20 feet below the mean level is noticed in winter. Thus we have a total difference in height of 50 feet in a channel not less than a quarter of a mile wide. This gives an approximate idea of the volume of this mighty stream. The rate of the current at the mean level, after the freshet has subsided, is about 7 miles an hour, while during the rise it is much more rapid. Above high-water mark the rocks show no traces of any erosion, but are sharp, jagged, and irregular to their very summits. There is no transportation of material, and the open plains of the Yukon are destitute of bowlders, terraces, and the other concomitants of glacial action.

The canyon in question is known as the "Ramparts." Near its western termination an immense dike of syenitic rock cuts through the hills and opposes a serious obstacle to the current, which has cut two narrow, deep channels, between which is a wide mass of syenite—an island at mean low water and a mass of seething foam during the freshets. This spot is known as the "Rapids," though the two channels afford no obstacles, except their very swift current, to navigation. The Yukon then rapidly widens, the hills become less elevated, and the Yukon meets the Tananà at the end of the Ramparts. The mountains on the left terminate in a rounded but high peak, called by the natives Mon-klág-at-liń. On the right of the Yukon is another, somewhat more distant from the river, which is known as Moh-klán-o-klikh. These two I have named the Twin Mountains. At the foot of the first named, the small islet forming the extreme point of the land between the Tananá and the Yukon is regarded by the various tribes of Indians as a neutral ground, where they all meet to trade in the spring, and so is named Nū-klúk-āh-yét. Opposite Nūklūkāhyét is a rounded, rather low but bold bluff of siliceous conglomerate or breccia. The left bank of the Yukon, and also of the Tananá as far as the eye can reach, is low, and this continues along the river to the sea, though the belt of alluvium varies in width at different points.

The right bank of the Tananá is high and rocky, composed of metamorphic sandstones and schists, and the natives state that farther up this river both banks are very mountainous. To the north the low Yukon Mountains and to the south successive ranges of high hills, including the Nowikákat and Kaiyûh mountains, pursue the same general course as the river, trending to the west and south. The rocks which compose these ranges are apparently metamorphic or trachytic, and have a general dip to the northwest or southeast. From Nūklūkāhyét to the Lebarge River the north bank is generally high and composed of schistose, siliceous, or metamorphic rocks, argillite, and a few patches of siliceous conglomerate and andesite, with alluvium where small rivers fall into the Yukon. The higher summits of the Nowikakât Range I found to be andesitic. Beyond the Lebarge River, as far as the Koyūkûk River, Kenai sandstones with vegetable remains form the prevailing strata. The Koyūkûk Sopka is a high peak (1,500 to 2,000 feet) composed of a soft, greenish, eruptive rock without stratification. From the Koyūkûk River to Kaltág the right bank is composed of the brown marine Miocene sandstones overlying the blue fresh-water sandstones of the Kenai series, much contorted and faulted. This formation extends westward to the Kuthlátno and Unālâklik rivers, where the marine strata terminate; the Kenai series come to the surface, intermixed with metamorphic argillites and slaty sandstones, the higher peaks of the rolling low hills which fill this district being eruptive or igneous rocks. From Kaltág to Lofka's the rocks of the right bank are mostly eruptive, exhibiting wonderful variations in color and sometimes containing zeolitic minerals. Below this metamorphic rocks again prevail, with conglomerate, until at the Mission amygdaloidal basalt and lava come down to the river and cover a wide belt of country between this point and Norton Sound near St. Michael. Eruptive and metamorphic rocks follow, and at the great southern bend blue Kenai sandstones and shales are again seen, followed by an immense plain or delta composed of alluvium brought down by the river. Point Romanoff and Cape Romanzoff are metamorphic, as well as some low ranges of hills to the southward.

The island of St. Michael, upon which was situated the redoubt of the same name, is of very recent origin. Traditions are current among the natives that it has been thrice submerged below the sea. Stuart and Egg islands are similar in formation. There are several well-defined craters on the island of St. Michael. One of them is occupied by a small lake. None of the rocks rise to any great height. At the settlement the rocks are almost entirely of a scoriaceous, amygdaloidal lava and basalt, roughly columnar on the beach near the boathouse, covered with layers of ashes, decayed pumice, vegetable mold, and peat. Specimens and reports brought from the region between the Yukon and Kuskoquim rivers show that the mountains of that region are essentially granitic, while bearing metamorphic quartzites and argillites upon their flanks.

PLEISTOCENE.

The epoch of the Pleistocene is practically outside the scope of this report. It might be said, briefly, that it included in Alaska great changes of level and marked volcanic activity, much as in California. Recent papers by G. M. Dawson,[1] W. P. Blake,[2] I. C. Russell,[3] and G. F. Wright,[4] bear on this topic and may be consulted with advantage.

It may be proper to mention here that I found several erratics with distinct glacial groovings on Woody Island, Kadiak, one of them in the Mission garden, but they are not abundant and are discovered only by careful search. As we left Kadiak, working northwest from Chiniak Bay through the strait between Kadiak, Afognak, and Spruce islands, it was noticed that the base-leveling of the lowlands was less and less elevated as we proceeded northward, and that no base-leveled bench is visible on the northwest shores of Kadiak and Afognak islands. The base-leveling referred to, while quite apparent in a general view, is less recognizable on the ground locally. The rocks of this region are apt to be tilted at a high angle and break into pinnacles and acute-angled blocks which more or less effectually mask the effect of the base-leveling when viewed at close quarters. The hardness of the

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[1]Trans. Royal Soc. Canada, 1890, vol. 8, sec. 4, pp. 3–74. Also, Bull. Geol. Soc. America, Vol. IV, pp. 427–431, 1892; and Vol. V, pp. 117–146, Feb., 1894.

[2]Glaciers of Alaska, in Am. Jour. Sci., July, 1867, 2d ser., vol. 44, No. 130, pp. 96-101, and Notes on the geography and geology of Russian America and the Stickeen River, H. Ex. Doc. 177, 1868, part 2, Washington, 19 pp., 8°. Also, T. A. Blake, "General topographical and geological features of the northwestern coast of America," etc., in Coast Survey Report for 1867, App., 18 E. 1869, pp. 281-290, Washington; and W. Libbey, jr., Bull. Amer. Geog. Soc., New York, 1886, 1887, No. 4, pp. 279-300.

[3]Notes on the surface geology of Alaska, Bull. Geol. Soc. America, March, 1890, Vol. I, pp. 99-162, Washington, 8°. Also, Mount St. Elias and its glaciers, Am. Jour. Sci. 3d. ser., vol. 43, No. 255, pp. 169-182, March, 1892; also, Malaspina Glacier, Jour. of Geol. Chicago, Vol. I, No. 3, pp. 219-245, 1893.

[4]The Muir Glacier, Am. Jour. Sci., Jan., 1887, 3d ser., vol. 33, pp. 1-18; also, Bull. Soc. Alaskan Ethn., 1888, No. 2, 8°, 22 pp.

rock, which would seem to make it a suitable medium for retaining glacial markings, if any existed, is more than made up for by its tendency to splinter. The difficulty in finding marks of erosion on the rocks in place is greatly added to by the dense blanket of moss and wiry herbage which in this moist climate covers everything except the vertical faces of the outcrops.

NOTES ON THE PALEONTOLOGY OF ALASKA.

The earlier formations are but little known in this part of the world; hence isolated notes, however unsatisfactory from a general standpoint, have a certain value, if only as indications for the future explorer.

SILURIAN.

The Upper Silurian (Clinton) *Halysites escharoides* Lam. is reported by Grewingk[1] as having been found in drift pebbles near Sitka, but no bed rock is known in that vicinity from which it might have been derived.

While engaged in field work on the coal field near Killisnoo, in the Alexander Archipelago, east of Sitka, we received from Mr. Brightman of that place some pieces of fossiliferous limestone obtained by him on the shore of Saginaw Bay, Kuiu Island, near Point Cornwallis. These comprised a broken and silicified, rather amorphous limestone, which was said to lie higher, and two thin, very fossiliferous slabs of sandstone, which it was stated were found at a lower level. The former is regarded by Mr. Charles Schuchert as probably of Silurian age, and an account of it and its fossil contents will be found in his report hereto appended.

DEVONIAN.

We owe to the late F. B. Meek[2] the demonstration of the existence of rocks of this age in Alaska. Fossils collected by Robert Kennicott, R. W. McFarlane, and the Rev. W. W. Kirkby determined the horizon of the deposits to be that of the Hamilton group of New York. Among the species collected in Russian America, now Alaska, were *Cyathophyllum arcticum* Meek, *Zaphrentis recta* Meek, *Z. Macfarlanei* Meek, *Paleocyclus Kirkbyi* Meek, *Favosites polymorpha* Goldfuss, *Atrypa aspera* Schlotheim, and *Cyrtina hamiltonensis* Hall.

The rocks containing these fossils are limestones, more or less impregnated with bitumen, and very similar to those which afford the petroleum of Pennsylvania. Their topographical aspect is that of low, undulating hills, seldom more than 500 feet in height, and usually much lower. In consequence of this, the Porcupine River in the Devonian area is a rather wide, shallow stream, obstructed by sand banks and shoals and without rapids, falls, or deep canyons. The dip is generally in a north-

[1] Beitrag zur Kenntniss, NW. Am. 1850, p. 20.

[2] Trans. Chicago Acad. Sci., Vol. I, 1867, pp. 61-114.

westerly direction, and the strata are more or less folded or distorted. The extent of the Devonian area on the banks of the Porcupine River, which enters the Yukon from the northeast near the Arctic circle, is as yet not precisely determined.

CARBONIFEROUS.

For many years the only definite locality for rocks of this age in Alaska was the coast of the Polar Sea, north of Bering Strait, between Cape Beaufort and Cape Thompson. They dip to the northwest, and consist of beds of limestone intermixed with siliceous and shaly layers.[1] Among the fossils from this locality are Encrinites, Lithostrotion, Tubipora, Turbinolia, Cyathophyllum, Caryophyllia, Productus, Spirifer, Orthis, and ? Dentalium.[2] A spirifer from this locality was loaned for examination by the California Academy of Sciences, and will be found referred to in Mr. Schuchert's report. Cape Lisburne is reported to reach a height of 1,000 feet, but most of these cliffs do not exceed 400 feet.

In 1867 I picked up near the "small houses" above the lower Ramparts on the Yukon River in Alaska a drift pebble containing *Chonetes glabra* Geinitz, a species of Productus, and some crinoid joints, which were identified by Meek as undoubtedly Carboniferous.

The limestones about the Muir glaciers in southeastern Alaska are mostly unfossiliferous, but in 1893 a coral was obtained from them by Prof. J. J. Stevenson which has been identified as a Lonsdaleia,[3] and they have consequently been referred to the Carboniferous epoch.

I have already spoken of a slab of limestone, containing fossils, obtained from Saginaw Bay, Kuiu Island, by Mr. Brightman, and presented to me. This contains a variety of distinctively Carboniferous brachiopods, and will be found described in Mr. Schuchert's report. Since our return a small lot of fossils from the west coast of Kuiu Island, opposite the south end of Baranoff Island, has been kindly forwarded to me by Mr. J. A. Becker, of Sitka.

MESOZOIC.

EARLIER EXPLORATIONS.

Rocks of this age were reported by Grewingk[4] upon the evidence of fossils collected by Elia Wossnessenski on the southern side of the peninsula of Alaska, near the Bay of Katmai. They were of a brown ironstone containing *Ammonites wossnessenskii*, *A. biplex*, *Belemnites paxillosus?*, and *Unio liassinus?*. The last was from a stratum probably different from the others.

The eastern promontory or point of Cold Bay, Alaska Peninsula, is low and surrounded by many dangerous rocks, avoided by the navi-

[1] Buckland, Appendix to Beechey's Voyage, Part II, p. 169, London, 1839, 4°.

[2] Grewingk, op. cit., p. 271.

[3] See Science, n. s., Vol. III, No. 53, January 3, 1896, pp. 33–34; also H. P. Cushing, "Notes on the areal geology of Glacier Bay, Alaska," in Trans. N. Y. Acad. Sci., Vol. XV; also H. F. Reid, "Glacier Bay and its glaciers, in Sixteenth Ann. Rept. U. S. Geol. Survey, Part I, 1896, pp. 421–461.

[4] Beitrag, pp. 48, 271–274.

gator. At the end of this cape Pinart obtained a number of specimens of *Monotis salinaria*, indicating the presenee there of Triassic beds. The species was identified and figured by Fischer.

Rocks carrying an abundant fauna are believed to cover a wide area, especially in the peninsular region of Alaska. Those eollected by us have been placed in the hands of Prof. Alpheus Hyatt for description and report, and I shall content myself here with a referenee to the principal sourees of information in the literature, and to a description of the localities from which they were obtained. Data in relation to the Mesozoie paleontology of Alaska may be sought in the works of Doroshin,[1] Grewingk,[2] Eichwald,[3] Fischer,[4] White,[5] and Lesquereux.[6]

The early explorers found on the portage from Katmai Bay to the northern side of the range, northwest from Katmai village, near the foot of the Kutlushat Volcano, a stratified ferruginous sandstone containing Aucella and Inoceramus. The same fossils were also obtained from the east coast of the peninsula, southwest of Nakchalitak Bay. At the high south point of entranee to Cold Bay (which is also ealled Studenaia, Puale, or Pualuk Bay), named Yaklok (Jaklak or Iaklök) Cape, a dark limestone containing belemnites was found by Doroshin, above which were sandstones with plant impressions resembling calamites, but really reeds of a more modern type.

At the entranee of Cook Inlet, near Port Graham, Doroshin found a heavy bed of limestone containing Janira and *Arcomya crassissima*, referred by Eichwald to the Neocomian.

On the east coast of the peninsula of Alaska, northward from Unalishakhtak Island, he reports a heavy bed of dark limestone with many ammonites, *Cardium imbricatarium*, and *Astarte germani*.

Beyond Chasik Island, on the west side of Cook Inlet, ammonites were found in a hard, black sandstone, dipping 25° to 40° N.

At Anchor Cape, Cook Inlet, at low water, quantities of *Inoceramus porrectus* are reported to be scattered among the pebbles, but no stratum from which they eould be derived is yet known above highwater mark.

A few species indicated but not described by Göppert[7] in 1861 are the same as those afterward deseribed by Eichwald.

[1] P. Doroshin. Einige Beobaehtungen und Bemerkungeu ueber das Gold-vorkommen in der Besitzungen der R. Am. Compagnie, Erman's Arehiv, xxv, pp. 229–237. Berlin, G. Reimer, 1866.

[2] Constantine Grewingk. Beitrag zur Kenntniss der orographisehen und geognostischen Beschaffenheit der Nord-West-Küste Amerikas, mit den anliegenden Inseln. St. Petersburg, Carl Kray, 1850. 8°, pp. iv, 351, ill.

[3] Eduard von Eichwald. Geognostisch-paleontologische Bemerkungen ueber die Halbinsel Mangisehlak und die Aleutischen Inseln. St. Petersburg, Kais. Akad. Wiss. 1871. 8°, pp. 200, pl. 16.

[4] Paul Fischer. Sur quelques fossiles de l'Alaska, in Voy. à la côte NW. de l'Am. 1870–1872, par Alphonse Pinart, Paris, 1875, pp. 33–36, pl. A.

[5] Charles A. White. On a small colleetion of Mesozoie fossils obtained in Alaska by Mr. W. H. Dall: Bull. U. S. Geol. Survey No. 4, pp. 10–16, pl. vi. 1884.

[6] Leo Lesquereux. List of recently identified fossil plants belonging to the U. S. National Museum, etc.: Proc. U. S. Nat. Mus., x, pp. 21–46, pls. i–iv, 1887. Also, plants obtained at Cape Lisburne by H. D. Woolfe: Proe. U. S. Nat. Mus., xi, pp. 31–33, 1888.

[7] Abhandl. der schles. Gesell. für vaterlandische Cultur, II, p. 201, 1861, and 1867, p. 50.

AUCELLA BEDS.

In 1871 Pinart obtained Aucella and Homomya from the rocks of Aniakchak Bay, near Sutkum, on the south side of the peninsula of Alaska, east of Chignik Bay, and also from a small bay which he calls Nakhalilik, south of the Chiginagak Volcano and west of the bay of the same name. These were identified and figured by Fischer.

In 1874, while surveying Port Möller, on the northern border of the peninsula north of the Shumagin Islands, I discovered at a bluff point at the head of the bay, about E. by S. by compass from the end of the long sand spit which protects the harbor, a limestone containing numerous fossils, chiefly *Aucella concentrica* Fischer, but including a Cyprina and Belemnites, described by Dr. White as new. A large Pecten of the Amusium type was also observed on an enormous slab of rock from which it could not be detached. In his discussion of these fossils Dr. White has expressed himself as follows (op. cit., pp. 10–13):

During the years 1840–1842, Elia Wossnessenski, while making zoological collections along the west coast of North America, obtained also a few fossils from Alaska. These were published by Constantine Grewingk, in Verhandlungen der Russisch-Kaiserlichen Mineralogischen Gesellschaft zu St. Peterburg, for the years 1848 and 1849, pp. 344–347. Those which Wossnessenski obtained from the bay of Katmai, on the southern coast of Alaska, Grewingk referred to the Jurassic; and some others, from Kadiak Island, he referred to the Tertiary. In the work presently to be noticed, Eichwald, however, declares the former to be of Neocomian, and the latter of Turonian age.

Alaska and the Aleutian Islands were visited during the years 1847–1852, by Peter Doroshin, a Russian mining engineer, who made some important collections of Mesozoic fossil mollusks from various localities in that region. Professor Eichwald, in 1872, published these fossils in St. Petersburg, together with other fossils which Doroshin had collected in the region of the Caspian Sea, the title of the work being "Geognostisch-Palaeontologische Bemerkungen ueber die Halbinsel Mangischlak und die Aleutischen Inseln." In that work, under the subtitle "Fossile Thiere des Neocom und Gault," pages 158–200, he describes sixty-two species of Mesozoic fossil mollusks from Alaska and the Aleutian Islands, and devotes sixteen plates to their illustration. It is this portion of Doroshin's collection that I propose to more especially refer to in this article, because I have now to consider a small collection of fossils from Alaska which probably came from the same formation. Eichwald is positive in his reference of this part of Doroshin's collection mainly to the Neocomian division of the Cretaceous, but in part to the Gault. He identifies certain species found in Alaska with some of those which have been long known in Russian strata, and which Keyserling referred to the Jurassic. Geologists have generally accepted this reference; but in the work on Alaskan fossils just referred to, Eichwald states that the Russian strata which bear the fossils alluded to are of Neocomian, and not of Jurassic age. He also regards the Russian and Alaskan strata which bear those fossils respectively as geologically equivalent, and makes at least one Alaskan species identical with a Russian one.

Prof. Jules Marcou[1] has called attention to the fact that there is a commingling of Jurassic and Lower Cretaceous types in both the Russian and Alaskan strata which have just been referred to; and that a similar condition of things exists in the island of Sakhalin and other portions of northern Asia.

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[1] Explication d'une seconde édition de la carte géologique de la terre, by Jules Marcou, pp. 121 and 137–140.

The Mesozoic collections which were made by Doroshin in Alaska are very important, but Eichwald's publication gives no comprehensive sketch of the geology of the Alaskan region. He refers some of the fossils from Chasik Island to the Gault, and some to the Neocomian; but he gives no description of two separate Mesozoic formations there. For want of definite information as to the geology of the region, one can not feel certain that all the fossils which Eichwald refers to the Neocomian really came from one and the same formation. If those fossils are all strictly of the same epoch, I think Eichwald's reference of them to the Neocomian is not unreasonable, because so many of those mollusks are of Cretaceous types; and yet Marcou's statement that there is a commingling of Jurassic and Neocomian types in those northern Mesozoic strata seems to be well supported. It has been thought by some paleontologists that Aucella is confined to Jurassic strata; but this genus is now known to exist in strata of undoubted Cretaceous age; and if the opinion of Eichwald is accepted, it will appear that Aucella is more characteristic of the Cretaceous than of Jurassic strata. At least it is plain that we can not now rely upon the presence of that genus as affording any proof of the Jurassic age of the strata which contains it.

During the prosecution of his work upon the United States Coast and Geodetic Survey along the western coast of the Alaskan Peninsula in the year 1874, Mr. W. H. Dall made a collection of Mesozoic invertebrate fossils which are of the same age as at least a part of those which which were collected by Doroshin. In his notes Mr. Dall designates the locality at which they were discovered as "Fossil Point, Port Möller;" and indicates its position as approximately in longitude 160° 31′ west, and latitude 45° 11′ north. The collection consists mainly of a species of Aucella, which is evidently identical with the forms which are figured on Eichwald's Plate XVII (loc. cit.), the specimens of which collection, like those of Doroshin's, are all in the condition of natural casts. The collection also contains a single valve of a species of Cyprina, and some fragments of a remarkably slender Belemnite. This collection is now the property of the United States National Museum, and permission to use it in the preparation of this article has been given by the Director of the Museum.

Two years previous to Mr. Dall's visit the same region was visited by M. Alph.-L. Pinart, who obtained some fossil shells of Mesozoic age upon the eastern side of the Alaskan Peninsula. These fossils evidently came from the same formation that furnished the shells which are figured by Eichwald on his Plate XVII. * * *

The fossils which were collected by M. Pinart were discussed by M. P. Fischer, in the report just cited, under the subtitle, "Sur quelques Fossiles de l'Alaska," pages 33–36, Plate A. Only two species were obtained by Pinart from the localities just mentioned, one of which Fischer places under Pholadomya (Homomya), but he gives it no specific name. The other he refers to the *Aucella concentrica* of Fischer. * * * If the Mesozoic collections of Dall and Pinart, and also that part of Doroshin's collection which Eichwald refers to the Neocomian, all really came from one and the same formation, the fauna thus represented has certainly much of Cretaceous, as well as of Jurassic character. This is true, even after excluding those species of Doroshin's collection which Eichwald refers to the Gault, and of course all that he refers to the Turonian. Still, this fauna has enough of Jurassic character, according to the views which have hitherto been generally entertained by paleontologists, to suggest that the strata which bear it occupy a transitional position, as indicated by Marcou. According to views now generally held by naturalists, transitional faunas ought to occur between all those which especially characterize each epoch respectively, and the suggestion of such a case for this Alaskan fauna seems to me to be reasonable.

Certain of the Cretaceous strata of Texas have been doubtfully referred to the Neocomian, but, with this exception, no North American strata south of the northern limit of the United States have hitherto been referred to the lower division of the Cretaceous series, and a broad hiatus has appeared to exist between those northern strata and the lowest of the Cretaceous rocks yet known south of the limit just referred to. Within a few years past, however, the labors of Dr. George M. Dawson in the coast region of British Columbia have brought to light some series of fossils which Mr. Whiteaves thinks prove the strata carrying them to be of the age of the Middle Cretaceous and the upper part of the Neocomian. (See Trans. Royal Soc. Canada, Sec. IV, 1882, p. 81.) Lately, also, some Ammonites have been sent to the United States National Museum by Mr. James G. Swan, from Skonum Point, British Columbia, which are suggestive of the earliest Cretaceous if not of Jurassic age, and they will doubtless be found to hold an important relation to the Cretaceous strata examined by Dr. Dawson, and also to the Alaskan Mesozoic strata which bear the fossils described in this article. In fact, it seems now to be evident that it is along the west coast of North America, from California to Alaska, that we are to look for the lower portion of the Cretaceous series on this continent. While these northwestern strata seem to be certainly older than the oldest of the Cretaceous strata in all that broad region occupied by Dakota, Montana, Wyoming, Colorado, and Utah, it is, nevertheless, true that in all that great region, where the Cretaceous and Jurassic strata are both exposed, the former seem always to rest conformably upon the latter. This apparent conformability over so wide a region shows how cautious one ought to be in concluding that deposition has been continuous in all cases where there is perfect conformity of strata, even if it is of great extent. * * *

Comparing these specimens [with each other and] also with the figures of Alaskan forms of Aucella which are given by M. Fischer on his Plate A, and also with those given by Eichwald on Plate XVII (loc. cit.), I can not doubt that they are all specifically identical with each other, nor that they all represent only one species. I have, however, some doubt as to which of the known European species of Aucella the Alaskan form ought to be referred to; but as it seems to agree more nearly with *A. concentrica* Fischer, I have designated it as a variety of that species.

In 1890 Mr. C. H. Townsend, of the United States Fish Commission steamer *Albatross*, visited Herendeen Bay, which makes into the lowlands of the peninsula just westward of Port Möller. Among the fossils collected were two varieties of Aucella in a somewhat different matrix.

Mr. W. J. Fisher, of St. Pauls, Kadiak, an old collaborator of the National Museum, has at different times sent in Aucella from the following localities on the south side of the peninsula bordering on Shelikoff Strait, which separates the Kadiak group from the mainland: Kanatua Bay, Cold Bay, Kiyiyukak Bay, Ugluak Bay (sometimes called Amber Bay), and Kamishak Bay, Cook Inlet. He has also found ammonites washed up on the beach of Kamishak Bay, and obtained others from near the portage on Kialagvit Bay.

EXPLORATIONS BY THE UNITED STATES GEOLOGICAL SURVEY IN 1895.

In 1895, Dr. Becker, Mr. C. W. Purington, and myself collected Mesozoic fossils in a number of localities.

TUXEDNI HARBOR.

Behind the island named Khazik in Tebienkoff's atlas, or Chasik in Eichwald's German text, but commonly called Chisik by the navigators in Cook Inlet, is an excellent harbor, called by Eichwald Tukusitnu Bay, and by the natives Tūk-sed′-ni. It is about midway on the west side of the inlet, between Cape Douglas and the North Foreland, and nearly abreast of the great volcano Iliamna.

Almost at the head of this harbor, on the main shore, is a bluff about 50 feet high. The upper stratum is about 4 feet of reddish gravel, below which is a barren yellowish sandstone composed of coarse quartz grains and about 15 feet thick. Below that is a limestone, of a dark-gray to pale color, in successive thin beds, apparently carrying only a single fauna, and underlain by a light-gray barren shale. The limestone contained an abundant fossil marine invertebrate fauna, and the wide area uncovered at low water and almost horizontal was an old Mesozoic beach, preserving the fossil shells, mud cracks, and other markings very perfectly, while overstrewn with the mussels, dead bivalves, and algæ of the living fauna. (Pl. LVIII.)

The northeast head of the harbor shows bluffs of limestone, sandstone, and conglomerate containing rolled pebbles, both pebbles and matrix containing the same fossils. At this place a particular belemnite was very common, while on the opposite shore, though the belemnite was not absent, *Inoceramus porrectus* Eichwald seemed to be the most abundant shell.

The bluffs on the island are much higher than the one described on the mainland. The upper portion of Chasik Island rises to a magnificent castellated summit of curiously eroded beds, which appeared to be conformable in every respect with one another and with the beds actually reached. The elevation can hardly be less than 2,000 feet.

An abundant collection was obtained at this locality, for a complete account of which the reader is referred to Professor Hyatt's report.

COLD BAY.

A locality already alluded to, and where we had heard that Mesozoic fossils were to be found, is Cold Bay, on the south shore of Alaska Peninsula, in latitude 57° 40′. At the southwest point of entrance of this bay is Cape Yaklok, near which Eichwald's supposed calamite was reported to be found, while the opposite point had furnished to Pinart his Triassic *Monotis salinaria*, though, unfortunately, we were not at the time of our visit reminded of the latter fact. Well up on the northeastern side of the bay is a valley which a stream drains, off the mouth of which is anchorage. Westward of the stream is a rather high (2,000–2,500 feet) ridge, recalling the Mesozoic mountains about Tūxedni Harbor, eroded in benches and having a singularly artificial aspect. From the first bench on this ridge Mr. Purington obtained a few Mesozoic fossils, the most noticeable of which was a Rhynchonella, and a few others were obtained at high-water mark where the same ridge came down to the beach. The matrix was coarse and friable and the specimens were few, but it seemed certain that the two lots belonged to the same fauna, which must range through at least 1,000 feet of strata. The rock is chiefly a calcareous shale, barren of fossils, which

FOSSILIFEROUS CLIFFS, TUXEDNI HARBOR.

disintegrates into small angular fragments, forming enormous and extremely regular talus slopes. Where a seam of sand and gravel or coarse sandstones is interleaved with the shales, there the fossils are found, but these seams are rare. We made the unavoidable mistake of hunting inside the bay for fossils, while the fruitful localities now appear to be just outside the points of entrance.

KIALAGVIT BAY.

Our next collecting ground for Mesozoic material was in Kialagvit Bay, a little to the west of Cold Bay. Here ammonites had been reported to Fisher by the natives. The bay is long, and is defended from the sea by a line of islets and reefs. The shores opposite are low and grassy near the water, and rise gradually to hills of much the same type as those of Cold Bay, though wanting the benches, as the beds were more steeply inclined. The grassy bank gave no very encouraging prospects as a collecting ground, but we finally went ashore where a few small outcroppings were visible, at a locality northeast of the mouth of the river which drains a valley up which the natives go to make a portage over to Ugashik Lake, on the north side of the peninsula. The bank is less than 100 feet high, and is mostly covered with a rank growth of herbage, but the small outcrops referred to afforded us, in the half hour given to it, as many fossils as could be carried away. A few blasts put in here would doubtless enable one to secure a shipload of fossils. The natives stated that in going over the portage they sometimes saw ammonites a foot in diameter among the fragments of talus. There can be no doubt that a very large area of Mesozoic rocks exists on the southern slopes of the peninsula, and a careful exploration would probably reward the paleontologist richly.

WOODY ISLAND, KADIAK.

In addition to the above-mentioned localities on the mainland, there are on some of the islands of the Kadiak group certain blackish, much contorted, slaty rocks which underlie unconformably the occasional Cenozoic sandstones, and have excited some interest in the past on account of the traces of precious metals which they have afforded. The writer made strenuous efforts to obtain some organic remains by which the age of these rocks could be determined. They present every feature petrologically which would indicate for them a greater age than the Mesozoic formations encountered on the mainland.

At Woody Island, Kadiak, on the shore facing Chiniak Bay, these rocks were found with the schistosity nearly vertical and in large part coinciding with the bedding. The dip and strike are locally multifarious, even in the extent of a few rods. The slate alternates with thin sandy layers, and forms very thin leaves in many places, but all are faulted and remarkably broken up by numerous dikes of hard grayish diorite. The slates are also much fissured with small cracks, mostly filled with calcite or quartz. The average strike is N. and S. magnetic, the dip 80°–85° E. The outcropping edges of the beds form successive parallel ridges, between which are long and narrow fresh-water lakes or marshes. The fossils were all found in a small area, less crushed than usual, on the westernmost margin. Above these the rocks were lighter-colored and profusely slickensided. The thickest section shows about 200 feet of strata, which may not include the whole series. The dioritic intrusions are usually transverse to the slaty beds. The upper surface is too broken and irregular to have retained any traces of glaciation or leveling. The fossils found were very few; one apparently a Posidonomya, the only bivalve: a singular organism like a flattened Dentalium, but probably a worm tube; and an alga which Professor Knowlton identifies with Eichwald's *Chondrites Heeri*, were the most conspicuous. It is not improbable that these slates are of Triassic age, but a final determination will require more prolonged study.

A preliminary discussion of the material obtained at the above-mentioned localities will be found in the appended report by Prof. Alpheus Hyatt.

PALEOBOTANY.

The following historical account of the paleobotanical literature of Alaska is quoted from Prof. F. H. Knowlton:[1]

One of the first accounts of fossil plants in Alaska is given by Dr. C. Grewingk[2] in his classical history of the northwest coast of America. This, however, is in the main a compilation, but the sources from which he derived his information are obscure, and I have not been able to find them. It is hardly probable that if found they would prove of much value. He reports coniferous wood from the islands of Kadiak and Unga and the Alaskan Peninsula, and dicotyledons (Alnus) and conifers (Taxodium) from Chugatch (Cook Inlet) and Unalaska. He also mentions a fern from Unga which he supposed to have some resemblance to *Neuropteris acutifolia*. It is probably the same as *Osmunda Doroschkiana* of Göppert, as there is no Carboniferous known from Unga.

A year later Grewingk again referred[3] to fossil plants in Alaska, especially to the fossil trunks on Unga Island, but nothing beyond this appears to have been noticed.

In 1861 Göppert reported[4] upon a small collection of fossil plants obtained in August, 1859, by Lieutenant Doroshin[5] from the islands of Kadiak (lat. 57½°), Uyak[6] (lat. 57½°), Atka[7] (lat. 52°), and Kootznahoo[8] (lat. 57½°). The last of these,

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[1] Proc. U. S. Nat. Mus., Vol. XVII, No. 998, pp. 207–240, 1894.

[2] Beitrag zur Kennt. d. orographischen u. geognostischen Beschaffenheit d. Nord-West-Küste Amerikas mit den anliegenden Inseln: Verhandl. Russ. k. mineral. Gesell. zu St. Peterburg, 1848–49, St. Petersburg, 1850, pp. 41, 93, 97, 124.

[3] Heidlb. Jahrb. Lit., 1851, p. 235.

[4] Ueber d. Tertiärfl. d. Polargegenden: Abhandl. d. schles. Gesell. f. vaterländ. Cult., 1861, Heft II, pp 201–204.

This paper is also published under the same title in Mélanges physique et chimiques tirés du Bulletin de l'Acad. Imp des sc. de St. Peterbourg, Tome IV, 1860–61, St. Petersburg, 1861, pp. 695–712.

[5] This name is written *Doroschkin* by Göppert, but is an obvious German rendering of the Russian *Doroshin*.

[6] This is probably from a bay of this name on the northwest coast of Kadiak, but as there are several unnamed islands in this bay it is possible that it may be one of them.

[7] This was written *Atha* by Göppert, but *Atka* is the correct spelling.

[8] Given as *Hudsoni* by Göppert, which is one of the earlier of the many renderings of the word *Kootznahoo*.

Kootznahoo, is an inlet in Admiralty Island, near Sitka. It afforded two species of dicotyledons and a single conifer. Göppert enumerated 11 species from the combined localities, a number of which were new, but did not give descriptions of them.

In 1866 this same collection was again referred to by Göppert,[1] but unfortunately the descriptions were not even then supplied, and consequently most of the names of new species remain nomina nuda.

In December, 1867, Prof. Oswald Heer, of Zurich, wrote a letter relating to Alaskan plants to Prof. A. E. Nordenskiöld, in Stockholm, which was published in the following year.[2] It was an enumeration of the plants brought back by Furuhjelm, and may be considered as an outline of Heer's larger work, which appeared in 1869. The plants are arranged according to localities and most of the new species briefly characterized.

In many respects the most important paper on the fossil plants of Alaska was Heer's Flora Fossilis Alaskana,[3] which was published in 1869. It was based, as stated above, upon collections brought back by Hjalmar Furuhjelm, of Helsingfors, Finland, who, as governor of the Russian-American possessions, resided for nearly ten years in Alaska. He made, it appears, a very large collection, most of which was lost on the Mexican coast by the stranding of the ship in which they were being sent home. The specimens which finally reached Europe were obtained from the island of Kniu,[4] near Sitka, and from the east side of Cook Inlet, a part coming from English Bay, better known as Port Graham (lat. 59° 21′; long. 151° 52′), and the rest from near a small stream known as the Ncnilchik (lat. 60° 9′). The latter place is about 50 miles north of Port Graham. This paper enumerates 56 species, of which number 19 were then new to science.

In 1871 Eichwald[5] made a reexamination of the plants collected by Lieutenant v. Doroshin that had first been studied, as above pointed out, by Göppert in 1861. Göppert, it will be remembered, did not give figures or descriptions of these plants in his paper. These were supplied by Eichwald, who also made use of Heer's Flora Fossilis Alaskana in working over the collection. He enumerated 9 species, 3 of which were newly named, although they had been recognized by Göppert or Heer. Eichwald also gave a list of the species reported from all parts of Alaska by Heer.

In 1882 Lesquereux published a paper entitled "Contributions to the Miocene flora of Alaska,"[6] which was based upon material brought back by Mr. William H. Dall, then of the United States Coast and Geodetic Survey. The plants, which, according to Lesquereux, were finely preserved, came from Coal Harbor, Unga Island; Kachemak Bay,[7] Cook Inlet, and Chignik Bay, Alaskan Peninsula (lat. 56½°). It enumerated 21 species, of which 7 were regarded as new to science. This paper was republished, but without the illustrations, in Lesquereux's Cretaceous and Tertiary Floras, 1883, pp. 257-263.

In 1882 Dr. J. S. Newberry also described new species of fossil plants from Alaska in his paper entitled "Brief descriptions of fossil plants, chiefly Tertiary, from Western North America."[8] They were collected by Captain Howard, United States Revenue Marine, in Cook Inlet and Admiralty Inlet,[9] and by the U. S. S. *Saginaw*, in the Kootznahoo Archipelago (lat. 57° 35′; long. 134° 19′), the last on February 18,

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[1] Abhandl. d. schles. Gesell. f. vaterländ. Cult. 1865-66; Breslau, 1867, p. 50.

[2] Utdrag ur ett bref af Prof. Oswald Heer rovande fossila vexter från Nordvestra Amerika, insamlade af Bergmästaren Hj. Furuhjelm. Öfversigt af Vetensaps-Akad. Förhandl. 1868. No. 1, pp. 63-68.

[3] Kongl. svensk. Vet.-Akad. Handl., Vol. VIII, No. 4, 1869, pp. 1-41, Pl. I-X.

[4] Written *Kuju* by Heer.

[5] Geognostisch-Palæontologische Bemerkungen über die Halbinsel Mangischlak u. die aleutischen Inseln, St. Petersburg, 1871, pp. 107-116, Pl. IV.

[6] Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), pp. 443-449, Pl. VI-X.

[7] Often called Chugachik Bay, and so written by Lesquereux.

[8] Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), pp. 502-514.

[9] This is presumably an error for Admiralty Island, there being no inlet of this name in Alaska.

1869. The figures illustrating these plants were prepared and the plates have been engraved and printed since 1871, but have not yet been formally issued. They were designed to form the illustrations of a monograph of the Hayden Geological Survey, for which the text was never supplied. A posthumous work, which will embrace them, is being prepared by Dr. Newberry's successor, Dr. Arthur Hollick, of Columbia College.

In 1887 Lesquereux published a paper entitled "List of recently identified fossil plants belonging to the United States National Museum, with descriptions of several new species."[1] This comprised a large amount of material that had been accumulating in the department of fossil plants since the founding of the Smithsonian Institution. Among them were a few species recorded as having been collected in the vicinity of Sitka, by E. W. Nelson,[2] and at Cape Lisburne, by H. D. Woolfe. The specimens from the latter place appear to have been a part of the collection that was described from the same locality in the following year, they having been accidentally separated.

In 1888, as stated above, Lesquereux published[3] an enumeration of plants obtained at Cape Lisburne by H. D. Woolfe. This collection included 10 species, of which number only one was regarded as new to science.

The last paper dealing with pre-glacial fossils is one by Felix,[4] in which he describes two species of silicified wood, the one obtained by Dr. Krause, of Berlin, on a basalt mountain south of Danaáka[5] and the other from Copper Island,[6] a small island in the southwestern part of the Bering Sea.

Mr. F. H. Herrick is the only one, so far as I now know, who has identified any of the interglacial wood. His paper, "Microscopical examination of wood from the buried forest, Muir Inlet, Alaska," is published as Supplement III to Harry Fielding Reid's paper, "Studies of Muir Glacier, Alaska."[7] Mr. Herrick identified the wood submitted to him with the tide-land spruce (*Picea Sitchensis*, Carr.) now living about the glacier.

A number of pieces of wood from the buried forest, Muir Glacier, obtained in 1892 by Mr. Reid, were submitted to me for examination. The report on them will be published also as an appendix to Mr. Reid's paper, soon to appear in the National Geographic Magazine. The species observed are recorded in their proper systematic position in the present paper.

The latest work dealing with fossil flora of Alaska, and this only incidentally, is the United States Geological Survey correlation paper on the Neocene, by W. H. Dall and G. D. Harris.[8]

In this work, accepting Heer's determination of the age of the formation, though pointing out that it was doubtful, the geology of these beds was considered under the head of "Miocene of the Kenai group," by me. This summary of what was then known of these beds was augmented by numerous unpublished notes made during my various journeys in Alaska from 1865 to 1880, with a discussion of the age of the formation and its geographical distribution, illustrated by a map

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[1] Proc. U. S. Nat. Mus., Vol. X, 1887, pp. 21-46, Pl. I-IV.

[2] I am informed by Mr. Nelson that he never visited Sitka and did not bring back any fossil plants from Alaska. This throws doubt on the specimens so recorded and their locality, and the collector remains unknown. I have retained them, however, as recorded by Lesquereux.

[3] Proc. U. S. Nat. Mus., Vol. XI. 1888, pp. 31-33, Pl. XVI, figs. 1-6; X, fig. 4.

[4] Zeitschr. d. D. geol. Gesell., Vol. XXXVIII, 1886, pp. 483-485.

[5] Fifty miles north of the head of Lynn Canal, in southwestern Alaska.

[6] This is really extra-limital, but has been included as being more nearly related to the Alaskan province than to any other.

[7] National Geographic Magazine, Vol. IV, 1893, pp. 75-78, figs. 4, 5.

[8] Bull. U. S. Geol. Survey No. 84, Washington, 1892, 8°, 349 pp., 3 maps; cf. pp. 234-252, and map.

of Alaska on which the localities and, when practicable, the areas were indicated.

Besides this publication and the review of the fossil flora of Alaska by Professor Knowlton, already quoted, additional light has been thrown on the Alaskan group by Sir William Dawson in his discussions of the paleobotany of the British Columbian region.[1] It will be found discussed elsewhere under the head of the Kenai group.

References to Mesozoic beds on the Yukon and its tributaries, near the boundary, are made by Dr. Geo. M. Dawson[2] and McConnell.[3] The presence of Aucella is noted, and occasional leaf or lignite beds are briefly mentioned. Since explorations by the U. S. Geological Survey in this region are planned for 1896, I content myself with referring to these discoveries.

[1] On fossil plants from the Similkameen Valley and other places in the southern interior of British Columbia: Trans. Royal Soc. Canada, Vol. VIII, 1890, pp. 75–91. Also On collections of Tertiary plants from the vicinity of the city Vancouver, British Columbia: Trans. Royal Soc. Canada, 2d ser., Vol. I, 1895, pp. 137–161, Pl. IV–VIII. Also, Dom. Geol. Survey, Report for 1877–78, p. 186B.

[2] Dom. Geol. Survey, Report for 1887–88, pp. 36B, 56B, 126B, 146B, 149B, 159B.

[3] Dom. Geol. Survey, Report for 1888–89, pp. 21D–22D.

APPENDIX I.

REPORT ON THE FOSSIL PLANTS COLLECTED IN ALASKA IN 1895 AS WELL AS AN ENUMERATION OF THOSE PREVIOUSLY KNOWN FROM THE SAME REGION, WITH A TABLE SHOWING THEIR RELATIVE DISTRIBUTION.

By F. H. Knowlton.

INTRODUCTION.

This report takes the form of a list of the fossil plants knownfrom Alaska, with an enumeration of the localities from which they have been collected and a table illustrating their distribution. Most of the plants are derived from beds of the Kenai formation and are supposed to be of Eocene or Oligocene age, formerly included under the Miocene. More thorough and fuller local collections and more careful discrimination of the several horizons and their respective floras may show that additional differentiation, geologically, is possible. The list and table are brought to date from my previous publication on the same subject.[1]

SYSTEMATIC ENUMERATION OF SPECIES.

ALGÆ.

CHONDRITES FILICIFORMIS Lesquereux.

Lesquereux, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 32, Pl. XVI, fig. 1.[2]

Cape Lisburne; H. D. Woolfe.

CHONDRITES HEERI Eichwald.

Eichwald, Geognost.-Paleontolog. Bemerk. ü. Halbinsel Mangischlak und Aleutischen Inseln, St. Petersb. 1871, p. 111, Pl. IV, fig. 1.

Chondrites sp. Heer, Fl. Foss. Alask., p. 21, Pl. X, fig. 5.

Kachemak Bay; H. Furuhjelm. Woody Island, Kadiak, in the crushed and metamorphosed hard (Triassic?) slates of this locality; Wm. H. Dall, 1895.

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[1] Review of the fossil flora of Alaska, with descriptions of new species: Proc. U. S. Nat. Mus., Vol. XVII, No. 998, 1894, pp. 207-240.

[2] The bibliographical citations refer exclusively to the occurrence of the various species in Alaska, and are not to be regarded as indicating the full synonymy.

EQUISETACEÆ.

EQUISETUM GLOBULOSUM Lesquereux.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 444; Cret. and Tert. Fl., p. 222, Pl. XLVIII, fig. 3.

This species was obtained at Unga Island by Wm. H. Dall. It was also obtained in the Bad Lands of Dakota, from which specimens the above-mentioned figure was made.

CALAMITES AMBIGUUS Eichwald.

EICHWALD, Geognost.-Paleontolog. Bemerk. ü. Halbinsel Mangischlak und Aleutischen Inseln, St. Petersb., 1871, p. 114, Pl IV, fig. 9.

Northeastern coast of Alaska peninsula north of Cape Yaklök south point of entrance to Cold Bay, and south of a small stream of that name; Eichwald.

This is a small fragment only 2 inches long and 1 inch wide, showing 12 longitudinal ribs. It appears to prove, if it is really a calamite, the presence of true Carboniferous strata in Alaska, but it is so very fragmentary that I can not but look upon it with question. The rocks in this vicinity are Mesozoic so far as known. Göppert, who first recognized its nature, also claimed to have observed leaves of Sigillaria, but this, too, requires confirmation.

FILICES.

PECOPTERIS DENTICULATA Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 32.

Cape Lisburne; H. D. Woolfe.

PTERIS SITKENSIS Heer.

HEER, Fl. Foss. Alask., p. 21, Pl. I, fig. 7*a*; EICHWALD, Geognost.-Paleontolog. Bemerk. ü. Halbinsel Mangischlak, und aleutischen Inseln, St. Petersb., 1871, p. 112.

Island of Kuiu, near Sitka; H. Furuhjelm.

OSMUNDA DOROSCHKIANA, Göppert.

GÖPPERT, Abhandl. d. schles. Gesell. f. Vaterländ.- Cult., 1861, Pt. II, p. 203; EICHWALD, Geognost.-Paleontolog., Bemerk. ü. Halbinsel Mangischlak und aleutischen Inseln, p. 112, Pl. IV, figs. 2, 3.

Osmunda Torelli, HEER, LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 444, Pl. VI, figs. 3–6.

Unga Island; Lieutenant Doroshin. Coal Harbor, Unga Island; Wm. H. Dall.

ASPIDIUM OERSTEDI Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 32.

Cape Lisburne; H. D. Woolfe.

ASPLENIUM FOERSTERI Debey and Ettinghausen.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 32.

Cape Lisburne; H. D. Woolfe.

ASPLENIUM DICKSONIANUM Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 32.

Cape Lisburne; H. D. Woolfe.

CONIFERÆ.

PINUS STARATSCHINI, Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 32.

Cape Lisburne; H. D. Woolfe.

PINUS species.

HEER, Fl. Foss. Alask., p. 23, Pl. I. fig. 11.

Port Graham; H. Furuhjelm.

SEQUOIA LANGSDORFII (Brongniart) Heer.

HEER, Fl. Foss. Alask., p. 23, Pl. I, fig. 10.

Port Graham and Nenilchik; H. Furuhjelm. Herendeen Bay; C. H. Townsend. Cape Douglas ash beds, and Chignik Bay mine, Wm. H. Dall, U. S. Geol. Survey, 1895.

SEQUOIA SPINOSA Newberry.

NEWBERRY, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 504; Plates, Pl. LIII. figs. 4, 5, *ined.*

Cook Inlet; Capt. Howard, United States Revenue Marine.

TAXODIUM DISTICHUM MIOCENUM Heer.

HEER, Fl. Foss. Alask., p. 21, Pl. I, fig. 6; III, fig. 11c; IV, fig. 5 *f. c.*

Port Graham and Nenilchik; H. Furuhjelm. Near Sitka; Lieutenant Doroshin. Herendeen Bay; C. H. Townsend. Sepphagen mine and De Groff tunnel, Kootznahoo Inlet, Admiralty Island; United States Geological Survey, 1895.

TAXODIUM TINAJORUM Heer.

HEER, Fl. Foss. Alask., p. 22, Pl. I, figs. 1-5.

Port Graham; H. Furuhjelm.

TAXODIUM TINAJORUM Heer; var.

EICHWALD, Geognost.-Paleontolog. Bemerk. ü. Halbinsel Mangischlak und aleutischen Inseln, St. Petersburg, 1871, p. 116, Pl. IV, fig. 4.

Port Graham (English Bay) and Nenilchik; Lieut. Doroshin.

GLYPTOSTROBUS EUROPÆUS (Brongniart) Heer.

HEER, Fl. Foss. Alask., p. 22, Pl. I, fig. 7 *b-f;* III, figs. 10, 11.

Kuiu Island, near Sitka; Lieutenant Doroshin. Nenilchik; H. Furuhjelm. Herendeen Bay; C. H. Townsend. De Groff tunnel, Admiralty Island, Kootznahoo lagoon; United States Geological Survey, 1895.

TAXITES OLRIKI Heer.

HEER, Fl. Foss. Alask., p. 23, Pl. I, fig. 8; II, 5*b*.

Port Graham; H. Furuhjelm.

THUITES (CHAMÆCYPARIS) ALASKENSIS Lesquereux.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 445, Pl. VI, figs. 7-9.

Coal Harbor, Unga Island; Wm. H. Dall.

GINKGO MULTINERVIS Heer.

LESQUEREUX, Proc. U. S. Nat. Mus.. Vol. XI, 1888, p. 31, Pl. XVI, fig. 6.

Cape Lisburne; H. D. Woolfe.

GINKGO ADIANTOIDES (Unger) Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. X, 1887, p. 35.

Sitka (?).

A single small doubtful fragment from Herendeen Bay; C. H. Townsend.

BAIERA PALMATA Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 31, Pl XVI, figs. 4, 5.

Cape Lisburne; H. D. Woolfe.

PICEA SITCHENSIS Carr.

HERRICK, National Geogr. Mag., Vol. IV, 1892, pp. 75-78, figs. 4, 5.—KNOWLTON Notes on the Examination of a Collection of Interglacial Wood from Muir, Glacier, Alaska: Jour. of Geology, Vol. III, 1895, pp. 529-530.

Muir Glacier; H. F. Reid.

TSUGA MERTENSIANA Carr.

KNOWLTON, Notes on the Examination of a Collection of Interglacial Wood from Muir Glacier, Alaska: Jour. of Geology, Vol. III, 1895, p 531.

Muir Glacier; H. F. Reid.

CUPRESSINOXYLON ERRATICUM Mercklin.

FELIX, Zeitschr. d. D. geol. Gesell., Vol. XXXVIII, 1886, p. 484.

Copper Island, southwestern part of Bering Sea; Dr. A. Krause.

PINITES PANNONICUS (Unger) Göppert.

GÖPPERT, Abhandl. d. schles. Gesell. 1861, p. 203.—HEER, Fl Foss. Alask., p. 23.

Southwestern end of Unga Island; Lieutenant Doroshin.

PITYOXYLON INÆQUALE Felix.

FELIX, Zeitschr. d. D. geol. Gesell. Vol. XXXVIII, 1886, p. 483, Pl. XII, fig. 3.

Basalt Mountain, south of Danaáku; Dr. A. Krause.

CYCADACEÆ.

ZAMITES ALASKANA Lesquereux.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 32, Pl. X, fig. 10.

Cape Lisburne; H. D. Woolfe.

PODOZAMITES LATIPENNIS Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 31, Pl. XVI, figs. 2, 3.

Cape Lisburne; H. D. Woolfe.

GRAMINEÆ.

PHRAGMITES ALASKANA Heer.

HEER, Fl. Foss. Alask., p. 24, Pl. I, fig. 12.

Port Graham; H. Furuhjelm.

POACITES TENUE-STRIATUS Heer.

HEER, Fl. Foss. Alask., p. 24, Pl. I, fig. 11; EICHWALD, Geognost.-Paleontolog. Bemerk. ü. Halbinsel Mangischlak und aleutischen Inseln, St. Petersburg, 1871, p. 114, Pl. IV, fig. 7.

Port Graham; H. Furuhjelm. Herendeen Bay; C. H. Townsend.

CYPERACEÆ.

CAREX SERVATA Heer.

HEER, Fl. Foss. Alask., p. 24, Pl. I, figs. 13, 13 *c. d.*

Port Graham; H. Furuhjelm. Herendeen Bay; C. H. Townsend.

CAREX, Leaves of.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. X, 1887, p. 36.

Sitka (?)

It is possible that this may be the *C. servata* of Heer, but as it is neither figured nor described I have retained it as probably separate.

ALISMACEÆ.

SAGITTARIA PULCHELLA Heer.

HEER, Fl. Foss. Alask., p. 25, Pl. I, fig. 15.

Nenilchik; H. Furuhjelm.

SAGITTARIA, species.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. X. 1887, p. 37.

Sitka (?).

IRIDACEÆ.

IRITES ALASKANA Lesquereux.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. X, 1887, p. 36.

Cape Lisburne; H. D. Woolfe.

SALICACEÆ.

POPULUS LATIOR Al. Braun.

HEER, Fl. Foss. Alask., p. 25, Pl. II, fig. 4.

Port Graham; H. Furuhjelm.

POPULUS GLANDULIFERA Al. Braun.

HEER, Fl. Foss. Alask., p. 26, Pl. II. figs. 1, 2.

Port Graham; H. Furuhjelm.

POPULUS BALSAMOIDES Göppert.

HEER, Fl. Foss. Alask., p. 26, Pl. II, fig. 3.
Populus eximia, GÖPPERT, Tert. fl. v. Schossnitz, p. 23; Abhandl. schles. Gesell., 1861, p. 203.

Port Graham; H. Furuhjelm. Kutznahoo, near Sitka; Lieutenant Doroshin.

POPULUS ZADDACHI Heer.

HEER, Fl. Foss. Alask., p. 26, Pl. II, fig. 5*a*.

Port Graham; H. Furuhjelm.

POPULUS LEUCOPHYLLA Unger.

HEER, Fl. Foss. Alask., p. 26, Pl. II, fig. 6.
Populus acerifolia, NEWBY., Later extinct floras of North America, p. 65.

Reported by Heer, but no locality given for Alaska.

POPULUS ARCTICA Heer.

LESQUEREUX, Proc. U. S. Nat. Mus. Vol. V, 1882 (1883), p. 447, Pl. IX, fig. 2.

Chignik Bay; Wm. H. Dall. De Groff tunnel, Kootznahoo lagoon, Admiralty Island; United States Geological Survey, 1895.

POPULUS RICHARDSONI Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 441, Pl. IX, fig. 1.

Chignik Bay; Wm. H. Dall. De Groff tunnel, Kootznahoo lagoon, Admiralty Island; United States Geological Survey, 1895.

SALIX VARIANS Göppert.

HEER, Fl. Foss. Alask., p. 27, Pl. II, fig. 8; III, figs. 1–3.
Salix Wimmeriana, GÖPPERT, Tert. fl. v. Schlossnitz, p. 26; Abhandl. schles. Gesell., 1861, p. 205.

Port Graham and Nenilchik; H. Furuhjelm.

SALIX MACROPHYLLA Heer.

Heer, Fl. Foss. Alask., p. 27, Pl. II, fig. 9.—Eichwald, Geognost.-Paleontolog. Bemerk. ü. Halbinsel Mangischlak und aleutischen Inseln, St. Petersb., 1871, p. 113, Pl. IV, fig. 5.

Port Graham; H. Furuhjelm.

SALIX LAVATERI Heer.

Heer, Fl. Foss. Alask., p. 27, Pl. II, fig. 10.

Port Graham; H. Furuhjelm.

SALIX RÆANA Heer.

Lesquereux, Proc U. S. Nat. Mus., Vol. V, 1882 (1883), p. 447, Pl. VIII, fig. 6.

Kachemak Bay, Cook Inlet; Wm. H. Dall.

SALIX INTEGRA Göppert.

Göppert, Abhandl. schles. Gesell., 1861, p. 202; op. cit., 1867, p. 50.

Nenilchik; Lieutenant Doroshin.

SALIX MINUTA Knowlton.

Knowlton, Proc. U. S. Nat. Mus. for 1894, p. 218, Pl. IX, fig. 1.

The leaf is found associated on the same piece of matrix as specimens of *Taxodium distichum miocenum*, *Paliurus Colombi*, and *Zizyphus Townsendi*.

Salix minuta was obtained at Herendeen Bay, by Mr. Charles H. Townsend, of the United States Fish Commission steamer *Albatross*. Type, No. 3761 U. S. Nat. Mus.

CUPULIFERÆ.

FAGUS ANTIPOFII Heer.

Heer, Fl. Foss. Alask., p. 30, Pl. V, fig. 4*a*; VII, figs. 4–8; VIII, fig. 1.

Port Graham, H. Furuhjelm. Kootznahoo lagoon, Admiralty Island; United States Geological Survey, 1895.

Five forms may be distinguished according to Heer, embracing *F. lancifolia*, Heer,[1] *F. pristina*, Sap.,[2] and *F. emarginata*, Heer.

FAGUS MACROPHYLLA Unger.

Heer, Fl. Foss. Alask., p. 31, Pl. VIII, fig. 2.

Port Graham; H. Furuhjelm.

FAGUS FERONLE Unger.

Heer, Fl. Foss. Alask., p. 31, Pl. VI, fig. 9.

Port Graham; H. Furuhjelm.

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[1] Heer: Öfversigt af Kongl. Vetenskaps Akad. Förhandl. 1868, p. 64.

[2] Saporta: Flore de Manosque; Ann. d. Sci. Nat., 1867, p. 69, Pl. VI, figs. 1–3.

FAGUS DEUCALIONIS Unger.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 447.

Kachemak Bay, Cook Inlet; Wm. H. Dall.

CASTANEA UNGERI Heer.

HEER, Fl. Foss. Alask., p. 32, Pl. VII, figs. 1–3.

Port Graham; H. Furuhjelm; Kuiu Island, Sitkan Archipelago.

QUERCUS PSEUDOCASTANEA Göppert.

HEER, Fl. Foss. Alask., p. 32, Pl. VI, figs. 3–5.

Port Graham; H. Furuhjelm.

QUERCUS FURUHJELMI Heer.

HEER, Fl. Foss. Alask., p. 32, Pl. V, fig. 10; VI, figs. 1, 2.

Port Graham; H. Furuhjelm.

QUERCUS PANDURATA Heer.

HEER, Fl. Foss. Alask., p. 33, Pl. VI, fig. 6.

Port Graham; H. Furuhjelm.

QUERCUS CHAMISSONIS Heer.

HEER, Fl. Foss. Alask., p. 33, Pl. VI, figs. 7, 8.

Port Graham; H. Furuhjelm.

QUERCUS DALLII Lesquereux.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 446, Pl. VIII, figs. 2–5; Cret. and Tert. Fl., p. 259.

Kachemak Bay, Cook Inlet; W. H. Dall.

CORYLUS MACQUARRII, (Forbes) Heer.

Plate IX, fig. 4.

HEER, Fl. Foss. Alask., p. 29, Pl. III, fig. 9, IV, figs. 1–5, 8.—EICHWALD, Geognost.-Paleontolog. Bemerk. ü. Halbinsel Mangischlak und Aleutischen Inseln, St. Petersburg, 1871, p. 113, Pl. IV, fig. 6.

Port Graham and Nenilchik; H. Furuhjelm. Kuiu Island; Lieut. Doroshin. Unga Island; Wm. H. Dall. Herendeen Bay; C. H. Townsend.

CORYLUS MACQUARRII var. MACROPHYLLA Heer.

HEER, Fl. Foss. Alask., p. 30, Pl. IV, figs. 6, 7.

Port Graham; H. Furuhjelm.

CARPINUS GRANDIS Unger.

HEER, Fl. Foss. Alask., p. 29, Pl II, fig. 12.—LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p 446.

Kachemak Bay, Cook Inlet; Wm. H. Dall. Port Graham; H. Furuhjelm. Kootznahoo lagoon, Admiralty Island; United States Geological Survey, 1895.

ALNUS KEFERSTEINII (Göppert) Unger.

HEER, Fl. Foss. Alask., p. 28, Pl. III, figs. 7, 8.

Nenilchik; H. Furuhjelm.

ALNUS KEFERSTEINII (Göppert) var.

HEER, Fl Foss. Alask., p. 28, Pl V, fig. 9.

Port Graham (?); H. Furuhjelm.

ALNUS ALASKANA Newberry.

NEWBERRY, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 509; Pl. XLVIII, fig. 8.

Kootznahoo Archipelago, latitude 57° 35′, longitude 134° 19′; U. S. S. *Saginaw*, February 18, 1869. Sent by Captain Meade.

ALNUS GRANDIFOLIA Newberry.

NEWBERRY, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 509.

Port Graham, Cook Inlet; Captain Howard, United States Revenue Marine.

ALNUS CORYLIFOLIA, Lesquereux.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 446, Pl. VII, figs. 1-4; Cret. and Tert. Fl., p. 258.

Kachemak Bay, Cook Inlet; Wm. H. Dall.

ALNUS RUBRA Bongard.

A branch of this species was found protruding from a gravel bank beneath an ice sheet 70 feet in thickness, on the eastern moraine of the Muir Glacier by Miss E. R. Scidmore.

BETULA PRISCA Ettingshausen.

HEER, Fl. Foss. Alask., p. 28, Pl. V, figs. 3–6.

Port Graham and Nenilchik; H. Furuhjelm.

BETULA GRANDIFOLIA Ettingshausen.

HEER, Fl. Foss. Alask., p. 29, Pl. V, fig. 8.

Port Graham; H. Furuhjelm.

BETULA ALASKANA Lesquereux.

LEQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 446, Pl. VI, fig. 14; Cret. and Tert. Fl., p. 258.

Chignik Bay, Alaska Peninsula; Wm. H. Dall.

MYRICACEÆ.

MYRICA BANKSIÆFOLIA Unger.

HEER, Fl. Foss. Alask., p. 28, Pl. II, fig. 11.

Port Graham; H. Furuhjelm.

MYRICA (COMPTONIA) CUSPIDATA (Lesquereux) Dawson.

Comptonia cuspidata, LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 445, Pl. VI, figs. 10–12; Cret. and Tert. Fl., p. 258.

Myrica (Comptonia) cuspidata, LESQUEREUX DAWSON, Trans. Roy. Soc. Canada, 1890, p. 80, fig. 9.

Coal Harbor, Unga Island; Wm. H. Dall.

MYRICA (COMPTONIA) PRÆMISSA (Lesquereux) Knowlton.

Comptonia præmissa, LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882, p. 445, Pl. VI, fig. 13.

Coal Harbor, Unga Island; Wm. H. Dall.

MYRICA VINDOBONENSIS (Ettingshausen) Heer.

HEER, Fl. Foss. Alask., p. 27, Pl. III, figs. 4, 5.

Nenilchik; H. Furuhjelm.

JUGLANDACEÆ.

JUGLANS ACUMINATA, Al. Braun.

HEER, Fl. Foss. Alask., p. 38, Pl. IX, fig. 1.

Port Graham; H. Furuhjelm.

JUGLANS NIGELLA Heer.

HEER, Fl. Foss. Alask., p. 38, Pl. IX, figs. 2–4.

Port Graham; H. Furuhjelm. Kootznahoo lagoon, Admiralty Island; United States Geological Survey, 1895.

JUGLANS PICROIDES Heer.

HEER, Fl. Foss. Alask., p. 39, Pl. IX, fig. 5.

Port Graham; H. Furuhjelm.

JUGLANS WOODIANA Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 449.

Chignik Bay; Wm. H. Dall.

JUGLANS TOWNSENDI Knowlton.

KNOWLTON, Proc. U. S. Nat. Mus. for 1894, p. 222, Pl. IX, fig. 5.

Herendeen Bay; C. H. Townsend.

URTICACEÆ.

FICUS ALASKANA Newberry.

NEWBERRY, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 512; Pl. LII, fig. 1; LV, figs. 1, 2.

Port Graham, Cook Inlet, and Admiralty Island; Captain Howard, United States Revenue Marine.

De Groff tunnel, Kootznahoo lagoon, Admiralty Island; United States Geological Survey, 1895.

FICUS MEMBRANACEA Newberry.

NEWBERRY, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 512; Pl. LIX, fig. 2.

Port Graham, Cook Inlet; Captain Howard, United States Revenue Marine.

PLANERA UNGERI Ettingshausen.

HEER, Fl. Foss. Alask., p. 34, Pl. V, fig. 2.

Port Graham; H. Furuhjelm.

ULMUS PLURINERVA Unger.

HEER, Fl. Foss. Alask., p. 34, Pl. V, fig. 1.

Port Graham; H. Furuhjelm.

ULMUS SORBIFOLIA Göppert.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 447, Pl. IX, fig. 3; Cret. and Tert. Fl., p. 260.

Kachemak Bay, Cook Inlet; Wm. H. Dall.

EBENACEÆ.

DIOSPYROS STENOSEPALA Heer.

HEER, Fl. Foss. Alask., p. 35, Pl. VIII, figs. 7, 8.

Nenilchik; H. Furuhjelm.

DIOSPYROS ALASKANA Schimper.

Diospyros Alaskana, SCHIMPER, Traité d. Pal. Vég., Vol. II, p. 945.
Diospyros lancifolia, LESQUEREUX in Heer, Fl. Foss. Alask., p. 35, Pl. III, fig. 12.

Nenilchik; H. Furuhjelm.

The name given this species by Lesquereux is preoccupied by a living species. It has consequently been changed by Schimper to *D. Alaskana*.

DIOSPYROS ANCEPS Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 448, Pl. X, figs. 1, 2; Cret. and Tert. Fl., p. 261.

Kachemak Bay, Cook Inlet; Wm. H. Dall. Kootznahoo lagoon, Admiralty Island; United States Geological Survey, 1895.

OLEACEÆ.

FRAXINUS HERENDEENENSIS Knowlton.

KNOWLTON, Proc. U. S. Nat. Mus. for 1894, p. 224, Pl. IX, fig. 7.

Herendeen Bay; C. H. Townsend.

ERICACEÆ.

ANDROMEDA GRAYANA Heer.

HEER, Fl. Foss. Alask., p. 34, Pl. VIII, fig. 5.

Port Graham; H. Furuhjelm. Kachemak Bay, 2 miles south of Eastland Canyon; United States Geological Survey, 1895.

VACCINIUM FRIESII Heer.

HEER, Fl. Foss. Alask., p. 35, Pl. VIII, fig. 4.

Port Graham; H. Furuhjelm.

VACCINIUM RETICULATUM Al. Braun.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 448, Pl. X, figs. 3-5; Cret. and Tert. Fl., p. 261.

Kachemak Bay, Cook Inlet; Wm. H. Dall.

CAPRIFOLIACEÆ.

VIBURNUM NORDENSKIÖLDI Heer.

HEER, Fl. Foss. Alask., p. 36, Pl. III, fig. 13.

Nenilchik; H. Furuhjelm.

CORNACEÆ.

NYSSA ARCTICA ? Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 447; Cret. and Tert. Fl., p. 261

Unga Island; Wm. H. Dall.

CORNUS ORBIFERA Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 448, Pl. X, fig. 6; Cret. and Tert. Fl., p. 262.

Kachemak Bay, Cook Inlet; Wm. H. Dall.

ARALIACEÆ.

HEDERA AURICULATA Heer.

HEER, Fl. Foss. Alask., p. 36, Pl. IX, fig. 6.

Port Graham: H. Furuhjelm.

ONAGRACEÆ.

TRAPA BOREALIS Heer.

HEER, Fl. Foss. Alask., p. 38, Pl. VIII, figs. 9–14.

Port Graham: H. Furuhjelm.

HAMAMELIDACEÆ.

LIQUIDAMBAR EUROPÆUM Al. Braun.

HEER, Fl. Foss. Alask., p. 25, Pl. II, fig. 7.

Port Graham; H. Furuhjelm.

ROSACEÆ.

SPIRÆA ANDERSONI Heer.

HEER, Fl. Foss. Alask., p. 39, Pl. VIII, fig. 3.

Port Graham; H. Furuhjelm.

PRUNUS VARIABILIS Newberry.

NEWBERRY, Proc. U. S. Nat Mus., Vol. V, 1882 (1883), p. 509, Pl. LII, figs. 3–5.

Port Graham, Cook Inlet; Captain Howard, United States Revenue Marine.

SAPINDACEÆ.

ACER MACROPTERUM Heer.

HEER, Fl. Foss. Alask., p. 37, Pl. IX, figs. 7–9.

Port Graham; H. Furuhjelm.

ACER TRILOBATUM PRODUCTUM (Al. Braun) Heer.

Herendeen Bay; C. H. Townsend.

ANACARDIACEÆ.

RHUS FRIGIDA Knowlton.

KNOWLTON, Proc. U. S. Nat. Mus. for 1894, p. 227, Pl. IX, fig. 6.

Herendeen Bay; C. H. Townsend.

VITACEÆ.

VITIS CRENATA Heer.

Heer, Fl. Foss. Alask., p. 36, Pl. VIII, fig. 6.

Port Graham; H. Furuhjelm. De Groff tunnel, Kootznahoo lagoon, Admiralty Island; United States Geological Survey, 1895.

VITIS ROTUNDIFOLIA Newberry.

Newberry, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 513; Pl. LI, fig. 2; LII, fig. 3.

Kootznahoo Inlet, Admirality Island; Captain Howard, United States Revenue Marine.

CELASTRACEÆ.

ELÆODENDRON HELVETICUM Heer.

Lesquereux, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 449, Pl. IX, fig. 4; Cret. and Tert. Fl., p. 263.

Coal Harbor, Unga Island; Wm. H. Dall.

CELASTRUS BOREALIS Heer.

Heer, Fl. Foss. Alask., p. 37, Pl. X, fig. 4.

Port Graham; H. Furuhjelm.

ILICINEÆ.

ILEX INSIGNIS Heer.

Heer, Fl. Foss. Alask., p. 37, Pl. X, fig. 1.

Port Graham; H. Furuhjelm.

RHAMNACEÆ.

ZIZYPHUS TOWNSENDI Knowlton.

Knowlton, Proc. U. S. Nat. Mus. for 1894, p. 229, Pl. IX, figs. 8, 9.

Herendeen Bay; C. H. Townsend.

PALIURUS COLOMBI Heer.

Knowlton, Proc. U. S. Nat. Mus. for 1894, p. 230, Pl. IX, fig. 2.

Herendeen Bay; C. H. Townsend.

TILIACEÆ.

TILIA ALASKANA Heer.

Heer, Fl. Foss. Alask., p. 36, Pl. X, figs. 2, 3.

Fort Graham; H. Furuhjelm.

MAGNOLIACEÆ.

MAGNOLIA NORDENSKIÖLDI Heer.

LESQUEREUX, Proc. U. S. Nat. Mus., Vol. V, 1882 (1883), p. 448, Pl. X, figs. 7–9; Cret. and Tert. Fl., p. 262.

Chignik Bay; Wm. H. Dall.

PHYLLITES ARCTICA Knowlton.

KNOWLTON, Proc. U. S. Nat. Mus. for 1894, p. 230, Pl. IX, figs. 10, 11.

Herendeen Bay; C. H. Townsend.

EXPLANATION OF THE TABLE.

A few words as to the manner in which the table was compiled may be of assistance in understanding its scope. I have given in the first nine columns the distribution of the fossil plants in Alaska itself. These columns also show the plants that are confined in their distribution to Alaska so far as now known. The remainder of the table is devoted to those having a distribution outside of Alaska, with the exception of those from Cape Lisburne. As the latter belong clearly to a much older horizon (Neocomian), about which there is little or no doubt, it has been thought unnecessary to increase the size of the table so as to show them.[1]

The next eight columns are devoted to the distribution of the Tertiary plants of Alaska in the United States and British Columbia. I have then selected a number of typical localities in different parts of the world at which places an abundant Upper Tertiary flora is developed, such as Disco Island and Atanekerdluk, Greenland, Spitzbergen, Sakhalin, Sinigalia, Œningen, etc. The last three columns are reserved for Oligocene, Miocene, and Pliocene, when the species under discussion is not found in any of the selected typical localities, yet occurs in these horizons in other localities.

DISCUSSION OF THE TABLE.

The fossil flora of Alaska, as presented in this paper, embraces 115 forms. Of this number, 1 is regarded as extra-limital and 3 are interglacial, being found also living about the Muir Glacier. Of the 111 forms remaining, no less than 46 are peculiar to Alaska, leaving 64 forms having an outside distribution. On removing the 9 species found at Cape Lisburne, about which, as pointed out above, there is little question of age, we have remaining only 55 species, or a little less than 50 per cent, upon which to depend for the determination of the bearing of the plants on the question of age.

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[1] The Cape Lisburne plants will be treated by Prof. Lester F. Ward in his forthcoming paper on the correlation of the fossil plants of the Lower Cretaceous.

An examination of the table yields the following numerical results: The Laramie has 3 species, of which 1 is doubtful; the post-Laramie beds of Colorado, 10 species; the Livingston beds of Montana, 6 species; the Fort Union beds, 16 species, of which 1 is doubtful; the Green River group, 9 species, of which 3 are in doubt; the Mackenzie River, 11 species; British Columbia has 7 species in the Miocene and 4 in the Laramie, with 2 common to both; California, represented by the auriferous gravels and allied formations, has 17 species, of which 3 are in doubt; the Eocene (Alum Bay, etc.), 6 species; the Greenland Miocene, as represented at Disco Island, Atanekerdluk, etc., has 29 species; the Miocene of Spitzbergen, 20 species; the island of Sakhalin (Siberia), 23 species; Sinigalia (Italy), 12 species; the so-called Baltic Miocene, 13 species; Œningen, 20 species; Oligocene, 11 species; Miocene, 33 species; Pliocene, 15 species.

By combining a number of the above localities which may be legitimately taken together we have still more impressive results. Thus, by the combining of the post-Laramie beds of Colorado with the Livingston beds of Montana, we have 13 species common to Alaska. The union of the Mackenzie River and Fort Union deposits gives 21 species common to Alaska; while Greenland, Spitzbergen, and Sakhalin have no fewer than 39 species out of the 55 species from Alaska. This last result shows, if we are to place any dependence in fossil plants, that the floras of Alaska, Greenland, Spitzbergen, and the island of Sakhalin are so closely related as to lead to the unavoidable conclusion that they grew under similar conditions and were synchronously deposited. The localities enumerated show that the circumpolar flora at that time was practically similar and continuous.[1]

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[1] A discussion of the age of these beds will be found under the head of the Kenai group in the preceding chapter on the Tertiary geology of Alaska, pp. 872-875.

Distribution of the fossil flora of Alaska.

Species.	Distribution in Alaska.								
	Cape Lisburne.	Sitka, and islands near.	Admiralty Island.	Cook Inlet.	Port Graham, Nenilchik.	Unga Island.	Chignik Bay.	Herendeen Bay.	Muir Glacier.
Chondrites filiciformis Lx	×								
Chondrites Heeri Eichw. (Triassic?)									
Equisetum globulosum Lx							×		
Calamites ambiguus Eichw									
Pecopteris denticulata Heer	×								
Pteris Sitkensis Heer		×							
Osmunda Doroschkiana Göpp						×			
Aspidium Œrstedi Heer	×								
Asplenium Foersteri Deb. and Ett	×								
Asplenium Dicksonianum Heer	×								
Pinus Staratschini Heer	×								
Pinus sp					×				
Sequoia Langsdorffii (Brongn.)					×		×		
Sequoia spinosa Newby				×					
Taxodium dist. miocenum Heer		×	×		×			×	
Taxodium Tinajorum Heer		×			×				
Taxodium Tinajorum var. Eichw					×				
Glyptostrobus Europaeus Brogniart		×			×			×	
Taxites Olriki Heer					×				
Thuites Alaskana Lx						×			
Ginkgo multinervis Heer	×								
Ginkgo adiantoides Heer		×						×	
Baiera palmata (Unger) Heer	×								
Picea Sitchensis Carr									×
Tsuga Mertensiana Carr									×
Cupressinoxylon erraticum Merck*									
Pinites pannonicus (Ung.) Göppert						×			
Pityoxylon inaequale Felix									
Zamites Alaskana Lx	×								
Podozamites latipennis Heer	×								
Phragmites Alaskana Heer					×				
Poacites tenuistriatus Heer					×			×	
Carex servata Heer					×			×	
Carex sp		×							
Sagittaria pulchella Heer					×				
Sagittaria sp		×							
Irites Alaskana Lx	×								
Populus latior Al. Braun					×				
Populus glandulifera Heer					×				
Populus balsamoides Heer		×			×				
Populus Zaddachi Heer					×				
Populus leucophylla Ung					×				

* This species is extra-limital.

Distribution of the fossil flora of Alaska.

Geological distribution outside of Alaska.																		
Laramie.	Post-Laramie of Colorado.	Livingston beds.	Fort Union.	Green River group.	Mackenzie River.	British Columbia. Laramie (L), Miocene (M).	California (auriferous gravels).	Eocene, Alum Bay, etc.	Greenland Miocene (Disco Island, Atanekerdluk).	Spitzbergen Miocene (Staratschin [S]).	Sakhalin (Siberia).	Sinigalia (Italy).	Baltic Miocene.	Œningen.	Oligocene.	Miocene.	Pliocene.	Remarks.
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....	×	....	....	....	....	....	×	....	×	....	×	....	×	..	....	×	..	Common in European Miocene.
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† This species comes from south of Danaaku, in southeastern Alaska.

Distribution of the fossil flora of Alaska—Continued.

Species.	Distribution in Alaska.								
	Cape Lisburne.	Sitka, and islands near.	Admiralty Island.	Cook Inlet.	Port Graham, Nenilchik.	Unga Island.	Chignik Bay	Herendeen Bay.	Muir Glacier.
Populus arctica Heer							×		
Populus Richardsoni Heer			×				×		
Salix varians Gopp					×				
Salix macrophylla Heer					×				
Salix Lavateri Heer					×				
Salix Ræana Heer					×				
Salix integra Göpp					×				
Salix minuta Knowlton								×	
Fagus Antipofii Heer			×		×				
Fagus macrophylla Ung					×				
Fagus Feroniæ Ung					×				
Fagus Deucalionis Ung					×				
Castanea Ungeri Heer		×			×				
Quercus pseudocastanea Göpp					×				
Quercus Furuhjelmi Heer					×				
Quercus pandurata Heer					×				
Quercus Chamissoni Heer					×				
Quercus Dallii Lx					×				
Corylus Macquarrii (Forbes) Heer		×			×	×		×	
Corlyus Macquarrii var. macrophylla Heer					×				
Carpinus grandis Ung			×	×	×				
Alnus Kefersteinii (Göpp) Unger					×				
Alnus Kefersteinii var. Heer					× ?				
Alnus Alaskana Lx			×						
Alnus grandifolia Newby					×				
Alnus corylifolia Newby				×					
Alnus rubra Bong									×
Betula prisca Ett									
Betula grandifolia Ett					×				
Betula Alaskana Lx							×		
Myrica banksiæfolia Ung					×				
Myrica cuspidata (Lx.) Kn						×			
Myrica præmissa (Lx.) Kn						×			
Myrica vindobonensis (Ett.) Heer					×				
Platanus nobilis Newby *									
Juglans acuminata Al. Br					×				
Juglans nigella Heer			×		×				
Juglans picroides Heer					×				
Juglans Woodiana Heer							×		

* From Topanika beds of Norton Sound (cf. Dall and Harris, Bull. U. S. Geol. Survey, No. 84, p. 246).

Distribution of the fossil flora of Alaska—Continued.

Geological distribution outside of Alaska.																		
Laramie.	Post-Laramie of Colorado.	Livingston beds.	Fort Union.	Green River group.	Mackenzie River.	British Columbia. Laramie (L), Miocene (M).	California (auriferous gravels.	Eocene, Alum Bay, etc.	Greenland Miocene (Disco Island, Atanekerdluk).	Spitzbergen Miocene (Staratschin [S]).	Sakhalin (Siberia).	Sinigalia (Italy).	Baltic Miocene.	Œningen.	Oligocene.	Miocene.	Pliocene.	Remarks.
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×	×	×	×		×	×L		×	×	×	×				×	×		Island of Mull.
				×		×L ?M	×		×	×	×		×			×	×	Birch Bay, Orcas Island. Eocene, rare; mainly Miocene.
				×			×		×	×	×		×	×	×	×	×	Few Eocene, but mainly Miocene.
			×							×	×	×	×	×		×		Few localities in Eocene, but mostly in Miocene.
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			×															
					×				×		×	×				×		A Miocene species very close to *J. rugosa* of United States.
			×						×		×							
				×												×		Also Vancouver.

Distribution of the fossil flora of Alaska—Continued.

Species.	Distribution in Alaska.								
	Cape Lisburne.	Sitka, and islands near.	Admiralty Island.	Cook Inlet.	Port Graham, Nenlchik.	Unga Island.	Chignik Bay.	Herendeen Bay.	Muir Glacier.
Juglans Townsendi Knowlton								×	
Ficus Alaskana Newby			×		×				
Ficus membranacea Newby					×				
Planera Ungeri Ett					×				
Ulmus plurinerva Ung					×				
Ulmus sorbifolia Göppert				×					
Diospyros stenosepala Heer					×				
Diospyros Alaskana Schimper					×				
Diospyros anceps Heer			×	×					
Fraxinus Herendeenensis Knowlton								×	
Andromeda Grayana Heer				×	×				
Vaccinium Friesii Heer					×				
Vaccinium reticulatum Al. Br				×					
Viburnum Nordenskiöldi Heer					×				
Nyssa arctica? Heer						×			
Cornus orbifera Heer				×					
Hedera auriculata Heer					×				
Trapa borealis Heer					×				
Liquidambar Europæum Al. Br					×				
Spiræa Andersoni Heer					×				
Prunus variabilis Newby					×				
Acer macropterum Heer					×				
Acer trilobatum productum (Al. Br.) Heer								×	
Rhus frigida Knowlton								×	
Vitis crenata Heer					×				
Vitis rotundifolia Newby			×						
Elæodendron Helveticum Heer						×			
Celastrus borealis Heer					×				
Ilex insignis Heer					×				
Zizyphus Townsendi Knowlton								×	
Paliurus Colombi Heer								×	
Tilia Alaskana Heer					×				
Magnolia Nordenskiöldi Heer							×		
Phyllites arctica Knowlton								×	

Distribution of the fossil flora of Alaska—Continued.

Geological distribution outside of Alaska																		Remarks
Laramie.	Post-Laramie of Colorado.	Livingston beds.	Fort Union.	Green River group.	Mackenzie River.	British Columbia, Laramie (L), Miocene (M).	California (auriferous gravels).	Eocene, Alum Bay, etc.	Greenland Miocene (Disco Island, Atanekerdluk).	Spitzbergen Miocene (Staratschin [S]).	Sakhalin (Siberia).	Sinigalia (Italy).	Baltic Miocene.	Œningen.	Oligocene.	Miocene.	Pliocene.	
				×			×	×	×		×	×	×	×		×	×	Very abundant in Greenland Miocene; mainly Miocene in other distribution.
							×	×	×		×	×		×		×	×	Largely Miocene in Europe.
																×		
													×	×				
										×								Also Vancouver.
				×								×		×		×		
			×?		×				×	×								
									×	×								Abundant in the Greenland Miocene
									×	×						×		
						×L					×							Laramie of Canada
							×		×			×		×		×	×	Mostly Miocene.
	×						×							×		×		
																×		
											×							
	×		×	×			×		×	×	×							Abundant in the Arctic Miocene.
					×				×	×	×							

APPENDIX II.

REPORT ON PALEOZOIC FOSSILS FROM ALASKA.

By Charles Schuchert,
United States National Museum.

SUMMARY.

It appears that Lieutenant Belcher and Mr. A. Collie were the first to secure Carboniferous fossils from Alaska, in the vicinity of Cape Thompson, north of Kotzebue Sound, Arctic Ocean. These were identified by Professor Buckland, and a list with a description of the locality is published in Captain Beechey's Voyage.[1] The same expedition also secured other Paleozoic fossils at Cape Lisburne, but, according to Grewingk,[1] Fischer and Kupreanoff first proved the age of these organisms to be Silurian. The same writer also reports *Halysites escharoides* (Silurian) as from Sitka.

Lieut. P. N. Doroshin traveled extensively in Alaska during the years 1847–1852, and at Cape Jaklök, at the southwest point of entrance to Cold Bay, Shelikoff Strait, north of Kadiak Island, found what appeared to be a Carboniferous plant. Eichwald[1] describes it as *Calamites ambiguus*. The same traveler also found in Alaska a trilobite, indicating Ordovician rocks, of which the locality is unknown. Lonsdaleia, a Carboniferous coral, was obtained by Professor Stevenson at Glacier Bay in 1893.

On the shore near Cape Thompson, Arctic Ocean, Mr. W. J. Fisher picked up among some pebbles a well-preserved specimen of *Spirifer condor*, an Upper Carboniferous brachiopod.

On Kuiu Island, in southern Alaska, Mr. W. Brightman secured two slabs of Carboniferous fossils denoting the Mountain Limestone of Europe, or the upper portion of the American Lower Carboniferous. From the same place a piece of limestone was collected containing fragments of a Conchidium, indicating rocks of Devonian age. Recently Mr. J. A. Becker has secured another lot of Devonian and Carboniferous fossils from the same region.

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[1] See Literature, p. 906.

DESCRIPTION OF LOCALITIES AND FOSSILS.

CAPE THOMPSON.

At Cape Thompson (latitude 67° 6′, longitude 165° 45′), which is about 400 miles in a straight line north of the mouths of the Yukon River, Belcher[1] observed Carboniferous strata. His description of this locality, to which Buckland has added observations on the fossils collected, is as follows:

The summit of the northernmost cape is composed of Carboniferous limestone, abounding with organic remains similar to those of the limestone of Derbyshire. It is also traversed by veins of chert of a blackish cast, varying in thickness from 6 inches to 2 feet. It here dips at an angle of 10° to the westward, and is succeeded, about halfway down the cliff, by blue and black argillaceous shale, with which it alternates in strata of 6 or 8 feet in thickness; and at about two-thirds down to the base, shale alone occupies the cliff, and becomes abundant in organic remains; it is occasionally interstratified by limestone, and much contorted.

At the end of the bay the limestone again commenced, of nearly the same character as A [the summit of the northernmost cape]; the chert, however, assuming a grayish cast, and containing organic remains in profusion. * * * Some chert, which had fallen from the center of the cliff, I found loaded with layers of shells (chiefly bivalves). (Lieutenant Belcher's notes, p. 171.)

Many specimens of this limestone from Cape Thompson are not distinguishable from the entrochal marble of Derbyshire, being almost entirely made up of fragments of encrinite. Many shells and corallines also appear to be identical with those of the Derbyshire limestone, e. g., the producta Martini, and other productæ, the species of which can not be accurately made out, from the imperfect state of the specimens; there are also many specimens of the lithostrotion, or basaltiform madreporite (Vol. II, Pl. V, figs. 3 and 6, Parkinson's Organic Remains: Columnaria of Goldfuss), and specimens of flustræ.

Mr. Collie, in his notes, speaks of impressions of trilobites also in the argillaceous slate of Cape Thompson, but I do not find any remains of these animals in the collection made by Lieutenant Belcher. (Buckland, p. 172.)

If Buckland's identifications are correct, then in *Productus martini* (=*P. semireticulatus* Martin), and *Madrepora basaltiformis* Conyb. and Phill. (=*Lithostrotion basaltiforme*), there is undoubted evidence of the existence of Carboniferous strata in the vicinity of Cape Thompson, which is confirmed by the *Spirifera condor* found by Fisher.

CAPE LISBURNE.

About 50 miles north of Cape Thompson, along the coast of Cape Lisburne, Mr. A. Collie[1] "found the brownish-gray and black strata of the cliffs to the southwest of it dipping south and west, at various but generally at considerable angles. * * * The perpendicular rocks appear to be composed of Mountain Limestone, the acclivities of slate and shale" (p. 172).

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[1] See Literature, p. 906.

The following fossils were collected at this point: Numerous "fractured terebratulæ" in a black, argillaceous slate; "Tubiporite, radiated head of encrinite," and "small terebratulæ in black swinestone"; "columnar madreporite" (p. 173).

These identifications do not indicate more than the presence at this place of Paleozoic strata; but, according to Grewingk, at this locality Fischer and Kupreanoff gathered from a dark calcareous shale the following fossils:

Cyathophyllum flexuosum (Lonsdale). Silurian.

Cyathophyllum cæspitosum Goldfuss=*C. cæspitosum* Ed. and Haime, of the Devonian (if *C. cæspitosum* Lonsdale=*C. articulatum* Ed. and Haime, of the Silurian).

Turbinolia mitrata Hisinger=*Aulocophyllum mitratum* Ed. and Haime. Silurian.

Caryophyllia truncata Hisinger=*Acervularia luxurians* Ed. and Haime. Silurian.

These corals indicate the presence of Silurian (Upper) beds at Cape Lisburne.

CAPE BEAUFORT.

The next locality in this Arctic region of Alaska where Paleozoic rocks are supposed to exist is Cape Beaufort, which is about 60 miles east of Cape Lisburne. Mr. Collie[1] describes the rock outcrops as follows:

> At Cape Beaufort is a high ridge, in which a narrow vein of coal is exposed, about a quarter of a mile from the beach. It is slaty, burns with a pure flame and rapid consumption. * * * The upper part of this eminence exhibits perpendicular faces toward the sea, and is strewed with broken blocks of slaty sandstone, containing carbonized impressions of reeds, both fluted and plain, generally flat * * * The sandstone is generally of a reddish-gray color (p. 173).

There is nothing in this description to indicate the age of these plants, but material subsequently collected by Henry D. Woolfe, from this region, Professor Ward "considers to indicate a Lower Cretaceous or possibly Upper Jurassic age."[1] Regarding the coal found at Cape Beaufort, Mr. Dall writes:

> [It] is of a very different quality from the lignites of the southern part of Alaska, and from the presence of corals, apparently referable to the epoch of the Carboniferous period, which were collected from the debris of the rocks adjacent, it has been assumed to be of that age. Similar coal crops out below low-water mark in many places northward to Point Belcher, and is pushed up on the beaches by the grounded ice floes, so that in some places nearly the whole of the beach gravel is made up of small fragments of coal. * * * It seems tolerably certain that strata covering a considerable range on the geologic column, beginning with the Silurian, are represented in the vicinity of Cape Lisburne, and that the coal-bearing strata may be Mesozoic rather than Paleozoic. (Dall, p. 249.)

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[1] See Literature, p. 906.

GLACIER BAY.

In a report of the meeting of the New York Academy of Sciences, December 16, 1895 (Am. Geol., Vol. XVII, 1896, p. 62), in a paper read by Prof. H. P. Cushing ("Notes on the areal geology of Glacier Bay, Alaska"), it is stated that a species of Lonsdaleia was picked up in Alaska by Professor Stevenson. This species was identified by Prof H. S. Williams, and is "regarded as demonstrative of the Carboniferous age of the beds" (Glacier Bay limestone). The locality is about 150 miles north of Kuiu Island, where Mr. Brightman and Mr. Becker collected the Carboniferous fossils described in this paper.

SITKA.

Grewingk[1] reports that *Catenipora escharoides* Goldfuss (= *Halysites escharoides* Ed. and Haime) was found near Sitka. This species is usually Silurian (Upper) in age.

CAPE YAKLÖK.

During the years 1847–1852, Lieut. P. Doroshin, in the interest of the Russian ministry of finance and the North American Trading Company, collected fossils at several localities in Alaska. The only probably Carboniferous fossil collected by him is a calamite, which Eichwald[1] named *Calamites ambiguus*. The fragment is about 2 inches long and is without nodes, so that a clear conception of the species can not be obtained. However, Eichwald writes:

> I agree with H. Goeppert that this [the piece of Calamites] is a true grauwacke, consisting of a fine-grained argillaceous sandstone, and indicates the Carboniferous formation. It occurs on the northeastern shore of Alaska north of Cape Yaklök, on the south shore of the river Yaklök (p. 115). [Further:] Impressions of Calamites are found at several places in Alaska and on the Aleutian Islands (p. 91).

Regarding *Calamites ambiguus*, Knowlton[1] writes:

> It appears to prove, if it is really a calamite, the presence of true Carboniferous strata in Alaska, but it is so very fragmentary that I can not but look upon it with question. Goeppert, who first recognized its nature, also claimed to have observed leaves of Sigillaria, but this, too, requires confirmation (p. 212).

Eichwald[1] says that "Doroshin has also collected in Alaska the head shield of a Lichas (Pl. VII, figs. 1, 2) which actually points to a grauwacke. In it, however, he did not observe other fossils" (p. 91). This trilobite is a Bathyuroid, and is probably of Ordovician age. Eichwald does not indicate the particular locality in Alaska from which it was derived.

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[1] See Literature, p. 906.

FOSSILS FROM KUIU ISLAND, ALASKA.

The small collection of fossils from Saginaw Bay, Kuiu Island, secured by Dr. Dall from Mr. Brightman, and another lot found by Mr. J. A. Becker on the same island, unmistakably indicate the presence there of Carboniferous and Devonian strata.

Devonian.—The fossils of Devonian age are Conchidium n. sp., Spirifer like *S. macronota*, and Spirifer related to *S. arrectus.*

Carboniferous.—On two pieces of a dark-colored sandstone there are preserved as casts, with the shell partially adhering, eight species of Brachiopoda. Those specifically identified are forms having a very extensive geographic distribution. However, if better-preserved material or free specimens were at hand, one or two of the species might prove to be distinct. These fossils indicate the age of the sandstone to be about that of the Mountain Limestone of Europe or the upper portion of the North American Lower Carboniferous. The *Spirifer condor* picked up by Mr. Fisher among the pebbles on the Arctic coast at Cape Thompson may be from higher or Permo-Carboniferous strata.

DEVONIAN FOSSILS.

Conchidium n. sp. Above the beach on Kuiu Island, Alaska, at Saginaw Bay, Mr. Brightman found a piece of white limestone, mottled with yellow, in which are numerous very fragmentary, siliceous specimens of a medium-sized Conchidium.

Conchidium n. sp. Of the same species four ventral valves were found by Mr. Becker which are similar to *C. knighti* in the angular plications and to *C. tenuistriata* in general form. The plications continue farther on the umbo-lateral slopes of the Alaska species than any other known form, which may indicate a younger age for the geological horizon than that of the above-mentioned species. It is also wider along the hinge line than *C. tenuistriatus*, and much like *C. baschkiricus* (Verneuil), from the Lower Devonian, occurring on the western side of the Urals, along the Juresan River. (United States National Museum Register, Nos. 25621, 26008.)

Spirifer sp. undet. I. A large alate species, with a high cardinal area and a smooth sinus. The only ventral valve present reminds us much of *S. macronota*, *S. pennata* Owen, and *S. manni.* (United States National Museum Register, No. 26006.)

Spirifer sp. undet. II. The only imperfect ventral valve present is apparently very similar to *S. arrecta* of the Oriskany sandstone. (United States National Museum Register, No. 26004.)

Chætetes sp. undet. A fragment of apparently a small hemispheric mass. (United States National Museum Register, No. 26005.)

Crinoidal fragments. (United States National Museum Register, No. 26007.)

CARBONIFEROUS FOSSILS FROM YELLOW SANDSTONE.

SPIRIFER, sp. indet.

In the yellow sandstone occurring above the beach on Kuiu Island, Alaska, associated with *S. duplicicostus* and *Productus longispinus* var. *alaskensis*, are fragments of a large spirifer with a very convex ventral valve. Internally the dental plates are thick and very high, much as in *S. neglectus* Hall. However, they do not appear to have extended anteriorly and bounded laterally the muscular area, as in that species. In general, the Alaska species resembles the North American *S. neglectus*. (United States National Museum Register, No. 25622.)

PRODUCTUS LONGISPINUS var. ALASKENSIS Schuchert.

Of this species there are eight specimens present, and all agree in form with *P. longispinus*, as figured by Davidson (Mon. British Carb. Brach., pl. 35, figs. 6 and 8), except that the striæ are much finer and more numerous. The mesial sinus of the ventral valve is also deeper and wider, even more so than in variety *lobatus* Sowerby, as figured by Davidson. The Alaska variety is probably more closely related to *P. inflatus* McChesney, since in size and lobation it is in harmony with a specimen of this species in the writer's collection from near Tuscumbia, Ala. The latter, however, also differs in having coarser striæ, and it is probably only a large, strongly lobate variety of *P. longispinus*.

Distribution.—P. longispinus is found in Scotland, Ireland, Belgium, Russia, India, Tasmania, Bolivia, and North America. The variety occurs above the beach on Kuiu Island, near Port Cornwallis, in a yellowish sandstone. (United States National Museum Register, Nos. 25623, 26003.)

CARBONIFEROUS FOSSILS FROM DARK-COLORED SANDSTONE.

SPIRIFER DUPLICICOSTUS Phillips.

1836. *Spirifera duplicicosta* Phillips, Geol. Yorkshire, Vol. II, p. 218, pl. 10, fig. 1; 1857, Davidson, Mon. British Carb. Brach., p. 24, pl, 3, figs 7, 10.

Of this species there is present a cast of a small ventral valve, which, on comparison with a specimen of the same size from the Mountain Limestone of Lancashire, England, proves to differ but slightly, the median sinus being more angular. The plications also are sharper and the bundling of the plications more prominent. These in both English and Alaskan specimens are crossed by very fine concentric striæ.

S. duplicicostus is closely related to *S. striatus*, and both are very variable species. The Alaska specimen, however, is more in harmony with the former than with the latter species.

Distribution.—Common in England, Ireland, and rarely in Scotland. In Alaska it occurs with *Spirifer pinguis* in the dark-colored sandstone near low-water mark and in the yellow sandstone above the beach on Kuiu Island. (United States National Museum Register, Nos. 25624, 25630.)

SPIRIFER PINGUIS Sowerby.

1820. *Spirifera pinguis* Sowerby, Min. Conch., Vol. III, p. 125, tab. 271; 1857, Davidson, Mon. British Carb. Brach., p. 50, pl. 10, figs. 1–12.

Of this species there is only one small dorsal valve present. It has five or six plications on each side of the median fold, the same number as in an example of the same size from the Carboniferous limestone of York, Ireland. Large Irish examples, however, may have as many as fifteen plications on the lateral half of each valve.

Distribution.—Abundant in the Mountain Limestone of England, Ireland, and Belgium. In Alaska it was found by Mr. Brightman in the sandstone (burnt-umber in color) near low-water mark on Kuiu Island, at Saginaw Bay, near Port Cornwallis. (United States National Museum Register, No. 25625.)

PRODUCTUS PUSTULOSUS Phillips.

1836. *Producta pustulosa* Phillips, Geol. Yorkshire, Vol. II, p. 7, fig. 15; 1857, Davidson, Mon. British Carb. Brach., p. 168, pl. 41, figs. 1–6; pl. 42, figs. 1–4.

This identification of the Alaskan material is based upon specimens of *P. pustulosus* in the writer's collection, from the Carboniferous limestone of Tournai, Belgium. Davidson's figures of Phillips's species, however, show far less numerous spine bases than occur on the specimen from Belgium or Alaska. In the present chaotic condition of Productus, and in view of the inconstancy of the great majority of species, it is unwise to attempt to determine what name this species will permanently bear.

Distribution.—Very common in the dark-colored sandstone occurring near low-water mark near Port Cornwallis, on Kuiu Island, at Saginaw Bay, Alaska. (United States National Museum Register, No. 25626.)

PRODUCTUS Sp. undet. A.

Among the fossils from the dark-colored sandstone of Kuiu Island there is a cast of a dorsal valve of a large, coarsely striated Productus. It appears to be quite distinct from any of the American, Indian, or European species of the group typified by *P. scabriculus*. However, since the ornamentation of the dorsal valve in species of this genus is sometimes quite different from that of the ventral valve, it is thought best to leave the form unnamed until more material is obtained. (United States National Museum Register, No. 25627.)

PRODUCTUS Sp. undet. B.

Two specimens of a small, highly arcuate Productus occur in the dark-colored sandstone of Kuiu Island. These are related to *P. youngianus* Davidson, from Scotland and Wales. They differ, however, from that form in having more numerous and finer radiating striæ. The material is not sufficient to give a diagnosis of the species. (United States National Museum Register, No. 25628.)

ORTHOTHETES CRENISTRIA (Phillips).

1836. *Spirifer crenistria* Phillips, Geol. Yorkshire, Vol. II, pl. 9, fig. 6.

1857. *Streptorhynchus crenistria* Davidson, Mon. British Carb. Brach., p. 124, pl. 26, fig. 1; pl. 27, figs. 1–5, ? 10; pl. 30, figs. 14–16.

1884. *Orthothetes crenistria* Waagen, Pal. Indica, Ser. XIII, Vol. I, p. 607; 1892, Hall and Clarke, Pal. New York, Vol. VIII, pt. I, p. 253.

Of this widely distributed species, six impressions of ventral valves are at hand. In general appearance they are very similar to *Orthis keokuk* Hall (=*Derbya keokuk*), but do not possess the median septum in the ventral muscular area so characteristic of Derbya. In the American Lower Carboniferous no species of Orthothetes are known above the Kinderhook formation, but in the Rocky Mountain region the genus seems to have persisted somewhat longer. In Europe, however, the genus Orthothetes is abundantly represented in the Mountain Limestone, and in India *O. semiplanus* occurs in the Permo-Carboniferous.

The specimens from Alaska agree very well with the figures given by Davidson (loc. cit., Pl. XXVI), except that in the English specimens the ventral muscular area is considerably smaller.

Distribution.—Common in England, Ireland, Belgium, and, according to Davidson, in India, Spitzbergen, and Australia. In Alaska, Mr. Brightman collected it near low-water mark, in sandstone (burnt-umber in color), near Port Cornwallis, Saginaw Bay, Kuiu Island. (United States National Museum Register, No. 25629.)

SPIRIFER CONDOR d'Orbigny.

1842. *Spirifer condor* d'Orbigny, Voyage dans l'Amérique Meridionale, Pal., p. 46, pl. 5, figs. 11–14; 1883, Waagen, Pal. Indica, Ser. XIII, Vol. I, p. 514.

1869. *Spirifer striatus* var. *multicostatus* Toula. Sitzb. der kais. Akad. der Wiss. Wien., p. 3, pl. 1, figs. 2–4.

1874. *Spirifera camerata* Derby (non Morton), Bull. Cornell Univ., Vol. I, p. 12, plates 1, 2, 4, 5; 1895, Derby, Bull. Mus. Comp. Zool., Vol. III, p. 279.

Of this Upper Carboniferous species there is present but one well-preserved, medium-sized specimen. *S. condor* is very closely related to *S. camerata* Morton and *S. striatus* Sowerby. It differs from the former in the nearly entire absence of the bundling of the ribs and the imbricating concentric striæ. In *S. striatus* the striæ are very fine, and do not imbricate, and the ribs are but slightly bundled.

Distribution.—In South America, *S. condor* occurs in Bolivia, Brazil, island of Titicaca, and Peru. It was found by Mr. Fisher in Alaska, among pebbles on the beach of Cape Thompson, Arctic Ocean, and is now in the collection of the California Academy of Sciences. In Russia, *S. condor* is represented by *S. tegulatus* Trautschold, and in India by *S. musakheylensis* Waagen. In the region of Mount Shasta, California, *S. condor*, or a closely allied species, is also known to occur.

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APPENDIX III.

REPORT ON THE MESOZOIC FOSSILS.

By Prof. Alpheus Hyatt.

The notes on fossils below are somewhat hastily written in response to the request for a report, but the determinations have not been hastily made:

(1) The slab from Woody Island, Kadiak, has what appears to be a large, much compressed species of Posidonomya, and I should think it might be Triassic or older, but there is no solid basis for this opinion.

(2) A slab from Cape Thompson, Arctic coast, has numerous specimens of Halobia, or Daonella, and is probably Triassic.

(3) The fossils from Kamishak Bay, Cook Inlet, are a species of Lytoceras, and another of Phylloceras, both apparently Upper Liassic, but I am still doubtful, because of one fragment that I have not yet made out satisfactorily, and also because of the uncertain indications with reference to exact age of rocks sometimes given by the Lytoceratinæ, and further because there are some Pelecypoda not yet examined.

(4) Kialagvit Bay (No. 1498). The Ammonitinæ from this locality are excellent, but belong to peculiar types, and I have been obliged to make a thorough investigation of the entire series of Hammatoceran groups in order to get clear ideas of their exact age. I can now state provisionally that this fauna is somewhat older than that of the lighter-colored limestone of Tuxedni Harbor, Chasik Island. The nearest relatives heretofore found belong to the lowest parts of the Inferior Oolite, in formations placed by many German and French authors in the Upper Lias. There is one species of Trigonia identical with a very rare species found at Taylorville, Cal., in the Mormon sandstone, one of the "Costatus" group, and the belemnites are also apparently very close allies of those in the same rocks.

(5) The fossils from Tuxedni Harbor, Chasik Island (No. 1495), are Inferior Oolite. A characteristic species of Trigonia is identical with one found in the Mormon sandstone at Taylorville, Cal., which is characteristic in that formation. There is also a well-preserved specimen

of Ammonitinæ, sufficient in itself to settle the age of this rock. It is a species of Sphæroceras, closely allied if not identical with the Mormon sandstone species, and a very close ally of the *Sphæroceras* (*Stephanoceras*) *giebelii* Gottsche, found in the Inferior Oolite west of Mendoza, in Chile. The aperture is well preserved in one specimen, and successful cleaning has exposed the inner whorls, so that no doubt can reasonably be held that this is a representative of the common fossils of this genus in the Inferior Oolite of Europe.

(6) The fauna found at Cold Harbor (No. 1497) is younger than that of Kialagvit Bay (No. 1498) or than that of Tuxedni Harbor (No. 1495). There is but one fossil in a fragmentary condition, but luckily this is the characteristic fossil collected by previous explorers and easily identified, although it is a young shell. It is the young of Cadoceras (Ammonites), described by Eichwald (Mangischlak u. d. aleutischen Inseln, p. 138, pls. 7–8), and found at the island of Chasik, and also, I think, shows that the so-called Cretacic species *Ammonites ishmæ* of Eichwald, found at several localities in Alaska, is the young of this same species. Nikitin, in various works (especially in Jura-Ablag. Rybinsk, Mologa, etc., Mem. Acad. St. Peterb., XXVIII, No. 5), has shown that Cadoceras is represented by closely allied forms in the Callovian of Russia, and it is a well-known genus of the Upper Jura in other localities in Europe.

The species of Ammonitinæ described by Grewingk and Eichwald are in my opinion all either Callovian or Inferior Oolite. The existence of the Cretaceous has not yet been demonstrated in Alaska, unless the Aucellæ described by Eichwald are Cretacic species. They are certainly not similar to the striated species of that genus occurring in the Upper Jura on the western slopes of the Sierra Nevada. It should be noted in this connection that Eichwald (p. 90) states that Aucellæ were found associated with species of Inocerami at two localities, and yet his *Inoceramus eximius*, *porrectus*, *operculiformis*, and *ambiguus* all certainly occur in the blue limestone of Tuxedni Harbor.

One of this author's species, *Inoceramus lucifer*, can not be positively cited as occurring at the same locality with those above noted, but it is identical with what Eichwald calls *Inoceramus ambiguus* junior. This leaves only one specimen unaccounted for as Jurassic, and that is his *Inoceramus cuneiformis* d'Orbigny, which is not figured and can not therefore be identified. Another fact is of importance in this connection. No Aucellæ occur among the fossils collected at the localities mentioned above which can be identified with certainty. There are two casts of left valves, with much flattened but incurved beaks, which look not unlike the right valves of species of this genus; but, if Aucellæ, these are very aberrant forms.

THE UINTAITE (GILSONITE) DEPOSITS OF UTAH.

BY

GEORGE HOMANS ELDRIDGE.

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THE UINTAITE DEPOSITS OF UTAH.

By George H. Eldridge.

PREFATORY.

In presenting the following account of the veins of uintaite in Utah, a desire to afford a general conception of the nature of the substance as well as of its mode of occurrence, and the advantages to be gained by a comparison with the closely related hydrocarbons, grahamite and albertite, have prompted the writer to avail himself freely of the results attained by those who have made the material the subject of special analytical research or have examined in person the deposits of the allied minerals.

The general map of the Uinta Basin (Pl. LIX) is a compilation from the surveys of King, Hayden, Wheeler, and Powell, The Geology of the High Plateaus of Utah by Dutton, and the maps of the General Land Office and the Post-Office Department. On comparison with the original an occasional alteration will be found, made for purposes of adjustment, or where a detail has come under the observation of the writer that escaped the others in their more general work. The special map of the region adjoining White River and the Colorado-Utah boundary (Pl. LX) is taken directly from the Hayden Atlas of Colorado without change. In both general and special maps, however, the location of the gilsonite veins is the writer's.

In coloring the general map, the broad geological divisions have alone been distinguished, this scheme being simple and sufficient for the purposes of the paper.

In the examination of the area described the writer has received aid of great value from Col. James F. Randlett, in command of Fort Duchesne, who is also the agent of the Uinta and Uncompahgre Indians, and both to him and to his officers this acknowledgment of their generous courtesy is made with sincere pleasure.

GENERAL CONSIDERATIONS CONCERNING UINTAITE.

The name uintaite was given by Prof. W. P. Blake,[1] in 1885, to a variety of asphalt found in the vicinity of the Uinta Mountains in Utah. The name gilsonite is of a later derivation than uintaite; it was adopted because of the substance having been brought into prominence as an article of utility by the efforts of Mr. S. H. Gilson, of Salt Lake. It is the name now commonly accepted in the trade.

The position of uintaite in the series of natural hydrocarbons is shown in Table I.

CLASSIFICATION OF HYDROCARBONS AND ALLIED SUBSTANCES.

TABLE I.—*Classification of natural hydrocarbons.*[2]

Hydrocarbons.	Bituminous	Gaseous		Marsh gas.
				"Natural gas."
		Fluid		Naphtha.
				Petroleum.
		Viscous (malthite)		Maltha.
				Mineral tar.
				Brea.
				Chapapote.
		Elastic		Elaterite. [Mineral caoutchouc.]
				Wurtzilite.
		Solid	Asphaltite	Albertite.
				Grahamite.
				Uintaite. [Gilsonite.]
			Coal	Bituminous coal.
				Semibituminous coal.
				Anthracite coal.
	Resinous			Succinite. [Amber.]
				Copalite.
				Ambrite, etc.
	Cereous			Ozocerite.
				Hatchettite, etc.
	Crystalline			Fichtelite.
				Hartite, etc.

Table II consists of bituminous compounds, natural and artificial, in character quite distinct from the materials of Table I. In their occurrence, however, there is evident relation between the two series at least as to origin, for uintaite, ozocerite, asphaltic limestones, and bituminous shales and sandstones are found throughout the same general locality and often in comparatively close proximity.

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[1] Uintaite, a new variety of asphaltum, from the Uintah Mountains, Utah: Eng. and Min. Jour., New York, Dec. 26, 1885, Vol. XL, p. 431.

[2] Trans. Am. Inst. Min. Eng., Vol. XVIII, p. 582.

TABLE II.—*Classification, or grouping, of natural and artificial bituminous compounds.*[1]

Bituminous compounds.	Natural.	Mixed with limestone ("asphaltic limestone").	Seyssel, Val de Travers, Lobsan, Illinois, Utah, and other localities.
		Mixed with silica and sand ("asphaltic sand").	California, Kentucky, Utah, and other localities. "Bituminous silica."
		Mixed with earthy matter ("asphaltic earth").	Trinidad, Cuba, California, Utah.
		Bituminous schists	Canada, California, Kentucky, Virginia, and other localities.
		Fluid	Thick oils from the distillation of petroleum. "Residuum."
	Artificial.	Viscous	Gas tar. Pitch.
		Solid	Refined Trinidad asphaltic earth Mastic of asphaltite. Gritted asphaltic mastic. Paving compounds.

The classification exhibited in the foregoing tables seems to the writer to be the most satisfactory of the several attempts encountered in a review of the literature of the subject. In this connection Professor Blake[2] observes that by the usage of many authorities "the word bitumen is generic rather than special, and is synonymous with asphaltum, both words being applied to the series of pure or nearly pure substances ranging from the fluid petroleum to solid asphaltum, but the name asphalt being generally reserved for the solid forms. The various natural and artificial mixtures of bitumen or of asphalt are not grouped with the pure minerals" in the tabulation followed.

"The use of the name bitumen for the whole series has the sanction of authority and long usage, but it is not sufficiently comprehensive for our present knowledge of the variety of substances grouped under the more exact designation of hydrocarbons."

Professor Blake also adds, with reference to a system suggested by Capt. F. V. Greene, that "it is objectionable in grouping the free or pure bitumens with the various mechanically formed rock mixtures under the one general term bitumen, which should be applied only to the varieties of pure and unmixed bitumens, while the other substances into which a variable portion of bitumen enters as a constituent may be better grouped and called by the name of bituminous compounds."

There is also a classification of the hydrocarbons based upon their chemical composition, but in view of the modifications necessary as investigation advances and the more easily comprehended arrangement based on physical characters alone, it is better, for technical purposes at least, to follow the latter.

[1] Ibid.

[2] Ibid, p. 580.

CHEMICAL RELATIONS BETWEEN THE HYDROCARBONS OF TABLE I.

The chemical relations between the hydrocarbons of Table I, were they worked out, would doubtless show the utmost complexity, for complexity exists even in the substances themselves, nearly all of which are separable by the action of solvents or by fractional distillation into two or more components that are in turn divisible into series of hydrocarbons, in many instances of great extent. No attempt will be made, however, to bring together even the more important results of analytical study, the writer contenting himself with the following general statements based upon those found in Dana's System of Mineralogy, edition of 1892.

In this work hatchettite and ozocerite are found among the simple hydrocarbons as members of the paraffin series C_nH_{2n+2}, while fichtelite, hartite, and a number of others occur in this division of the hydrocarbons, but of series other than the paraffin, and in many instances altogether of doubtful reference.

The resinous compounds belong to the class of oxygenated hydrocarbons, the membership in which is very extended and of great variety. Concerning this class, Dana remarks that it embraces "chiefly the numerous kinds of native fossil resins, many of which are included under the generic term 'amber;' also other more or less closely related substances. In general, in these compounds, weak acids (succinic acids, formic acid, butyric acid, cinnamic acid, etc.), or acid anhydrides, are prominent."

Between the coals—especially the bituminous and cannel varieties—and the resinous and asphaltite divisions of this table, relations are readily found; indeed, for a number of years, only two or three decades ago, grahamite, on account of its composition, was regarded by men high in authority as a true coal, notwithstanding their wholly different mode of occurrence. Albertite, grahamite, and uintaite are now, however, accepted as closely related varieties of asphaltum. Elaterite and wurtzilite, in outward appearance, bear a striking resemblance to them, but are easily distinguished by their behavior toward solvents and by their marked sectile and elastic properties. Yet, while uintaite itself is exceedingly brittle, one of its leading features, developed in the manufacture of black japans and varnishes made from it, is this very property of elasticity, attainable in such perfection in no other hydrocarbon compound except elaterite and wurtzilite.

Dana, under elaterite, in remarking upon the results attained by the authorities which he consulted, states that this substance "appears to be partly a carbohydrogen near ozocerite and partly an oxygenated insoluble material." This statement becomes of special interest when it is observed that the two materials occur in Utah in localities not very far removed from each other; much nearer than are the localities of ozocerite and uintaite.

Table III.—*Resemblances and differences between the asphaltites, with asphaltum added for comparison.*

[The portion in italics is taken from Dana's System of Mineralogy, sixth edition.]

Substance.	Structure.	Fracture.	Color.	Luster.	Hardness.	Specific gravity.	Fusibility.	Solubility in—											Remarks.
								Heavy oils and fats, lubricating petroleum.	Light oils.	Benzine.	Naphtha.	Turpentine.	CS_2.	Alcohol.	Ether.	Chloroform.	Acids.	Alkalies.	
Asphaltum (mineral pitch).	.....	.....	*Brown or brownish black.*	*Like black pitch*	.....	*1 to 1.8*	*Melts at 90° to 100°*	.....	.....	.....	.....	*Mostly or wholly* ..	.....	*Partly*	*Partly or wholly.*				
Albertite[1]	..... Prismatic at right angles to walls.	..... Conchoidal: brittle	*Jet black* ..... Black; streak black; powder black to faint brown.	*Brilliant; pitchlike*	*1 to 2* 3	*1.097* 1.08 to 1.11 Jackson and Hayes.	*Incipient in candle flame: softens in boiling water.* In spirit flame intumesces and emits gas, but does not melt like asphalt. Melts in closed tube. Adheres to paper.	.....	.....	.....	.....	*30 per cent*	.....	*Trace*	*4 per cent*	.....	.....	.....	..... Becomes electrified when rubbed. Composition close to jet.
Grahamite[2]	..... In vein: for 2 or 3 inches from walls, coarsely granular, with cuboidal clevage; then 15 inches of columnar structure on either side, columns at right angles to walls; then 18 inches in center, compact and massive.	..... Conchoidal brittle.	*Pitch black* ..... Black, but streak and powder dark chocolate brown.	*Brilliant* ..... Brilliant: center less so than the two other portions of vein.	*2*	*1.14* 1.145	*Melts imperfectly with decomposition of surface, but in this state interior may be drawn into threads.* Heated above 400° F. it softens. Endures a temperature far above the fusing point of asphalts in general. Behaves much like coking coal.	.....	.....	*Partly* .. Partly.	*Partly* .. Partly.	*Mostly* ..... Swells and nearly all dissolves.	*Wholly* ..... Readily soluble except ash.	*Not at all* ..... Completely insoluble.	*Partly* ..... Partly.	*Wholly* ..... Readily soluble except ash.	..... Colored brown by strong sulphuric acid.	..... Not acted upon.	*Jenney has manufactured grahamite from petroleum.*
Uintaite[3] (gilsonite)	..... Cuboidal and pencillate for 6 inches next to walls: balance compact and massive.	..... Conchoidal: brittle.	*Black; streak and powder brown.* Black, but powder and streak brown, with shade of red; streak lighter than that of albertite.	*Brilliant—which is retained after melting.* Brilliant.	*2 to 2.5* 2 to 2.5	*1.065 to 1.070* 1.065 to 1.070	*Easily fusible in candle flame; acts like sealing wax, but more adhesive to cold paper.* Readily fusible in candle flame; apparently unchanged by successive melting and cooling.	*Readily soluble.* Readily soluble.	*Less so* ..	.....	.....	*Freely in hot; less in cold.* Readily when aided by heat.	..... Entirely (Day).	*Soluble* ..... Not readily, but by repeated treatment up to 54.6 per cent.	*Slowly when in powder.* Not wholly.	..... Partially.	.....	.....	*A nonconductor. Electrically excited by friction.* Electrically excited by friction. Soluble also in melted wax, ozocerite, spermaceti, stearin, etc. (Blake); also (Day) in petroleum ether and glacial acetic acid. Composition close to torbanite.

[1] Dawson.

[2] Wurtz.

[3] { Eldridge as to occurrence.
{ Blake and Day as to properties—fusibility, solubility, and specific gravity.

Substance.	Structure.	Fracture.	Color.	
Asphaltum (mineral pitch).			*Brown or brownish black*	*Li*
Albertite[1]			*Jet black*	*Br*
	Prismatic at right angles to walls.	Conchoidal; brittle.	Black; streak black; powder black to faint brown.	n rubbed. et.
Grahamite[2]			*Pitch black*	*Bd graham-*
	In vein: for 2 or 3 inches from walls, coarsely granular, with cuboidal clevage; then 15 inches of columnar structure on either side, columns at right angles to walls; then 18 inches in center, compact and massive.	Conchoidal; brittle.	Black, but streak and powder dark chocolate brown.	Br
Uintaite[3] (gilsonite)			*Black; streak and powder brown.*	*Bricaly ex-*
	Cuboidal and pencillate for 6 inches next to walls; balance compact and massive.	Conchoidal; brittle.	Black, but powder and streak brown, with shade of red; streak lighter than that of albertite.	By friction. l wax, ozo- earin, etc. petroleum etic acid. orbanite.

[1] Dawson.

The viscous compounds stand between the solid asphaltum on the one hand and petroleum on the other. "The fluid kinds," observes Dana, "change into the solid by the loss of volatile matter by a process of oxidation, which is said to consist first in the loss of hydrogen and finally in the oxygenation of a portion of the mass." The intimate relations in the manner of occurrence between the lighter gaseous hydrocarbons and petroleum are well known.

The distinguishing features of the substances in Table II are sufficiently familiar not to require special explanation.

RESEMBLANCES AND DIFFERENCES BETWEEN THE ASPHALTITES.

Albertite, grahamite, and uintaite, forming the group of asphaltites, are very closely related to one another in composition and mode of occurrence, but are yet distinguishable by their behavior toward solvents, by the action of heat upon them—their fusibility, so called—and by one or more of their other properties. The following table of resemblances and differences has been in the main compiled from such authorities as have been immediately available, including Peckham, Blake, Wurtz, William C. Day, Dawson, Hitchcock, and others. The writer has also added the results of his own observations in the field.

ANALYSIS OF UINTAITE.

Uintaite is at present under analytical investigation by Dr. William C. Day, of Swarthmore College, Pennsylvania. From a published account[1] of the results thus far obtained by him the following extracts have been made by way of affording a slight insight into the nature of the substance.

A determination of the volatile matter, fixed residue, and ash gave:

Proportions of volatile matter, fixed residue, and ash in uintaite.

	Per cent.
Volatile matter	56.46
Fixed residue	43.43
Ash	.10
	99.99

Dr. Day says:

Working on a larger scale, and distilling a weighed quantity of gilsonite from a retort, the following result was obtained: 136.1 grams of gilsonite gave 76.1 grams

[1] Investigation of Utah gilsonite, a variety of asphalt, Dr. William C. Day: Jour. Franklin Inst., Vol. CXL, No. 837, Sept., 1895.

of distillate. The percentage of volatile matter is thus 55.9. Comparing this result with that above, it is evident that all the volatile matter is condensable.

He also gives as a result of his observation the following percentage composition of gilsonite (uintaite):

Elementary composition of uintaite.

	Per cent.
Carbon	88.30
Hydrogen	9.96
Sulphur	1.32
Ash	.10
Oxygen and nitrogen (undetermined)	.32
	100.00

In concluding this paper Dr. Day observes:

As a result of the present investigation, a method of obtaining from gilsonite a number of acids has been outlined. By further study of those acids and their derivatives a knowledge of the hydrocarbons present in the mineral may be gained. The distillation experiments have shown that a number of radically different series of hydrocarbons is obtained, and that the paraffin series is one of them, and very probably, also, the naphthene series is another. No aromatic hydrocarbons appear to be present, or at most only in small quantity, as in no part of the work have derivatives of these bodies suggested themselves. Conclusions drawn from distillation products of a mineral hydrocarbon as to the constitution of the latter are necessarily unsafe, on account of the decompositions which take place during the distillation. Much safer conclusions may be drawn from products obtained without distillation from the original material directly by the action of reagents such as nitric and sulphuric acids.

GEOLOGY OF THE UINTA BASIN.

TOPOGRAPHICAL FEATURES.

The Uinta Basin has a general altitude of 5,000 to 6,000 feet and an entire length from east to west of about 170 miles, extending from the Wasatch Mountains to the White River Plateau, 60 miles east of the Colorado-Utah line. The maximum distance across the basin, north and south, is a little over 100 miles, and is practically coincident with the 110th meridian. On the north the basin is confined by the anticline of the Uinta Mountains, the peaks of which rise to nearly 13,700 feet; by the eastward continuation of this range, the Yampa Plateau, between 8,000 and 9,000 feet in altitude; and by the Danforth Hills, which form the divide between the headwaters of the White and Yampa rivers. On the south the basin is limited by the summit of the Roan or Book Plateau, a monoclinal ridge which beyond overlooks the valleys of the Price, Green, and Grand rivers, tributaries of the Colorado, and presents to them for nearly 200 miles a bold and almost continuous cliff having a general height of between 2,000 and 3,000 feet. Locally the cliff may be broken along formation lines by benches a mile or more in width, the result of differences in material and texture between the several series of rocks. Such benches may become the sites of grassy parks, always with more or less timber.

The interior of the Uinta Basin is a comparatively shallow depression, the axis of which lies nearer the northern side. The several Eocene-Tertiary formations involved in its constitution, consisting of soft sandstones, argillaceous shales, and thin-bedded limestones, have been irregularly eroded into lofty tables, mesas, ridges, buttes, and spires, presenting in general a scene of much desolation and decay.

Green River divides the basin into east and west halves, and has cut for itself, except for 15 to 20 miles across the center of the depression, canyons from 1,000 to 3,000 feet deep, wholly impassable except by boat at great risk. In the center of the basin this stream receives from the east and west, respectively, the White and Duchesne rivers. The former, the larger, enters the open valley about 12 miles above its confluence with the Green, after a tortuous course through 70 or 80 miles of continuous canyon in the shales and sandstones of the Green River and Bridger formations. Along this portion of the stream the bottom lands are reduced to a few short, narrow strips at long intervals. The valley of the Duchesne River is open for 50 miles above its mouth, the bluffs being low and the channel bordered for most of the distance with rich bottom lands from 1 to 2 miles wide. North of this stream the uplands, particularly in the vicinity of the Uinta River and Lake Fork, afford extensive areas that are both arable and irrigable, and under ditch have already given evidence of great productive capacity. Both streams flow comparatively full, the water derived from the Uinta Range being of great purity. The same conditions prevail in regard to Ashley Creek, the valley of which is one of the most fertile of Utah. East of the Green River, however, but little water is received from the mountains, and the center of the basin becomes almost arid, in a few localities only there being grass sufficient even for light grazing.

The southern half of the basin, and especially that portion east of the Green River, presents a scene of great desolation and decay. Canyons with labyrinthine intricacy have been cut to depths of between 1,000 and 2,000 feet in the backs of the strata forming the Roan or Book Plateau, while the intervening ridges are sharp and crumbling, developing spires and buttes and castellated forms in greatest profusion, all seemingly ready to topple to pieces at the first heavy storm. Little water is carried in any of these gorges, and this, except at their heads, through the sands of their channels instead of as surface flows. It is, moreover, frequently impregnated with alkali, which abounds in all the formations of the locality. In Indian Canyon, a tributary of Strawberry Valley, there are numerous warm springs, which are said to remain open all winter. Parks, well grassed and timbered, and with more or less water, may be found at the heads of many of the canyons, features that relieve the general barrenness found in other localities. Of such canyons as the foregoing the White and Duchesne valleys receive a number, while one of the most rugged in the basin is that of the Minnie Maud, which enters directly into Green River from the west, 15 or 20 miles below the Duchesne.

THE FORMATIONS.

DESCRIPTION.

For simplicity the essential characteristics of the formations entering into the structure of the Uinta Basin have been placed in tabular form.

TABLE IV.—*Formations of the Uinta Basin.*

Period.	Formation name.	Maximum thickness, in feet.[1]	Description.
Pleistocene		25	Gravel, sand, and clay, according to formations from which derived. From the Uinta Mountains, a coarse gravel of quartzite; from the Roan or Book Plateau, sand, argillaceous shale, and clay. Some of the gravel is secondary, having first been a constituent of the Eocene.
Eocene	Uinta	500 to 1,000.	Conglomerates, sandstone, and shale, the first two predominating, especially toward top. Material derived chiefly from Paleozoic quartzites of Uinta Range and Yampa Plateau. Prevailing color, red to pink, though many of the sandstones are a rusty yellow to brown.[2]
	Washakie	200	Sandstones and shales. Difficultly recognizable.[3]
	Bridger	600 to 1,000.	Conglomerates, sandstones, shales, and an occasional 1 to 2 foot layer of white limestone. Sandstones prevail; they are heavy-bedded, somewhat ferruginous, and of gray to rusty yellow and chocolate-brown color. Conglomerate fine. Formation identified by vertebrate remains, according to investigators.

[1] Largely estimated.

[2] According to J. B. Hatcher the Uinta of this region is the equivalent of Osborn's Diplacodon elatus beds.

[3] Equivalent to the top of the Bridger, according to some authorities.

TABLE IV.—*Formations of the Uinta Basin*—Continued.

Period.	Formation name.	Maximum thickness, in feet.[1]	Description.
Eocene	Green River	2,000	Calcareous shales and thin limestones. Shales and limestones bituminous, locally in a degree to be of economic value. Prevailing color gray, weathering light. Occasional thin sandstone layers, becoming more prominent toward top. Country, deeply eroded.
	Wasatch	1,000 to 1,500.	Conglomerates and sandstones in heavy beds. Red color.
Cretaceous	Laramie	1,000	Sandstones and shales. Sandstones largely predominate. They occur in heavy beds; color, yellowish-gray. Shales gray. Near base of formation, workable coal beds: coal, locally, coking; general quality, excellent.
	Montana	2,000?	Shales: argillaceous, leaden-gray. Occasional limestone concretions. Upper 200 to 300 feet beds more sandy and firmer in outcrop. In general of the same appearance as elsewhere in the West.
	Colorado	300?	Shales: argillaceous, black. Few thin limestones. Ironstones. General appearance same as elsewhere in West.
	Dakota	500	Sandstones: heavy-bedded, gray; separated by thin shaly layers. Of usual appearance in the West.
Juratrias	Jura	500 to 700.	Shales and thin limestones. Former brilliantly variegated; latter drab. Gypsum in heavy local beds.
	Trias (Red Beds)	2,000	Conglomerates, grits, and sandstones. Last prevail. Color: lower half, red; middle, buff; top, white. Few thin limestones.
Carboniferous.[2]	Permo-Carboniferous.	200 to 500.	Calcareous shales and argillaceous rocks and clays, intervening between the Coal Measures and Trias, conformable to both, and carrying Permo-Carboniferous fossils.

[1] Largely estimated.

[2] United States Geological Survey of the Fortieth Parallel, Clarence King, Vol. I, pp. 153–154.

TABLE IV.—*Formations of the Uinta Basin*—Continued.

Period.	Formation name.	Maximum thickness, in feet.[1]	Description.
Carboniferous.[2]	Upper Carboniferous.	2,000 to 2,500.	Limestones—some layers cherty—and calciferous sandstones variable in thickness. The series prevailingly of heavy limestone at base, with varying thin-bedded intercalations of lime and sand near top, always capped with a zone of highly cherty Bellerophon-bearing limestone. Rich in upper coal measure fossils.
	Weber quartzite.	12,000.	A series of siliceous beds—impure sandstones at east end of Uinta uplift, gradually compacted to quartzite in western portion of range. These beds are intercalated with groups of clay shales and occasional conglomerate sheets, which contain round, rolled Archean pebbles.
Archean[3]	....	....	Pure white quartzites, hornblendic schists, and hydromica (paragonite) schists, richly charged with garnet, staurolite, and minute crystals of cyanite.

[1] Largely estimated.

[2] United States Geological Survey of the Fortieth Parallel, Clarence King, Vol. 1, pp. 153–154.

[3] United States Geological Survey of the Fortieth Parallel, Clarence King, Vol. 1, p. 43.

The formations below the Laramie are, so far as at present known, of minor importance in their relations to the occurrence of the hard asphalts, and will be mentioned only incidentally in what follows.

INTERRELATIONS OF THE TERTIARY AND CRETACEOUS SERIES.

The Tertiary series, embracing the Wasatch, Green River, Bridger, Washakie, and Uinta formations, is wholly Eocene in age. In the relationship of the several members one with another they have been found in uncomformability in many localities, particularly in the Green River, Washakie, and Vermilion Creek basins, to the north: in the Uinta Basin, however, the evidence of unconformabilities at the different horizons is not so pronounced, and, indeed, except in the case of the

Uinta along its northern border, the only suggestion of interruption to continuity of deposition from base to summit of the series that was observed by the writer is a sharp change in sedimentation between the several members. But it is to be remarked that the writer's investigations in this direction were far from exhaustive.

Between the Cretaceous and Tertiary series, also, along the face of the Roan or Book Cliffs, there is no apparent break except in character of sediments. Along the base of the Uinta Range, however, evidences of unconformity between the two series and within the Tertiary exist in force. There is here a most marked overlap of the Uinta upon the older formations from Laramie to Carboniferous, the youngest Tertiary resting in turn against the Upper Coal Measures, the Permo-Carboniferous, the Juratrias, and the several members of the Cretaceous. In the ridge forming the western rim of the Ashley Valley it rests unconformably upon different layers of the Laramie, with a somewhat indistinct divergence in dip, but in passing southward the difference in dip apparently diminishes and the formations are upturned to nearly the same degree, 5° to 20°, the dip being west. In Raven Ridge, 30 miles east of Green River and south of the Yampa Plateau, according to the observations of the Hayden Survey, which were in greater detail than the writer's, the Laramie, at first overlain by the Uinta, is, in passing eastward, separated from it by the Wasatch formation. A little farther on, the Green River formation appears between the Wasatch and the Uinta, and finally is itself separated from the youngest Tertiary by the beds of the Bridger formation. The interrelationship of the Laramie and Tertiaries is shown on the special map of the region, Pl. LX.

AREAL DISTRIBUTION OF THE FORMATIONS.

The Paleozoic series of strata, in uplifted position, form the northern rim of the Uinta Basin—the Uinta Range and Yampa Plateau. In some instances the Paleozoic is overlain to great altitudes by the Juratrias, and in one or two localities even by the Dakota and shaly members of the Cretaceous. At all points along the base of the ranges, except where overlapped by the Tertiaries, the Mesozoic beds form more or less prominent fringing reefs, and in the divide between Ashley and Uinta creeks, and in Raven Ridge, 20 miles east of Green River, the Tertiaries also are inclined at considerable angles—20° to 30°—shallowing rapidly, however, to the south and west. At the eastern end of the Uinta Basin, in the White River Plateau, the same general conditions prevail. At the western end of the basin the geology is more complex, the surface distribution of the formations which here enter into the structure of the eastern side of the great Wasatch fault monocline having been considerably modified by the presence of eruptives and by erosion. The southern rim of the Uinta Basin—the Roan or Book Plateau—is formed of the Green River, Wasatch, and Laramie strata, which to the south overlook the valleys of the Grand and Price rivers, a broad belt of Montana shales lying at the base of the cliffs. The Green River series forms the summit of the greater portion of the plateau, although occasionally the Wasatch constitutes the divide. From here northward to the vicinity of White River and Minnie Maud Creek the Green River beds, with dip somewhat steeper than the topographic slope, form the floor of the Uinta Basin.

No line of demarcation between the Green River and Bridger formations has ever been established, at least in the Uinta Basin, and it is uncertain just where one series ends and the other begins. Between the well-pronounced shales of the Green River, interbedded with a few sandstones, and the heavy, shale-divided sandstones referred by the paleontologist to the Bridger, there is a zone in which neither shale nor sandstone predominates in any great degree. In general, however, the southern line of the Bridger probably lies, for that portion of the basin west of Green River, at the summit of the divide between Minnie Maud and Argyle creeks on the south and the Duchesne and Strawberry valleys on the north, and in the region east of Green River, at or a little south of White River, appearing also in the canyon walls of the latter stream. Too little is known of the Washakie formation, considered, indeed, by many as the upper member of the Bridger, to distinguish it from the main body of this formation below, and their line of demarcation is undefined.[1]

The southern line of the Uinta formation, where crossed by the Price and Fort Duchesne stage road, lies about 5 miles south of the Duchesne River, and pursues a nearly east-and-west direction for its entire length. The westward extension of this line, as of the others between the Eocene formations, was not traced by the writer, nor has it ever been defined, so far as he can learn. It is probable, however, that it continues well toward the head of the Strawberry Valley. The eastward extension is that determined by the Hayden Survey, and is given on the special map, Pl. LX. The northern boundary of the Uinta formation in the western half of the field follows closely the base of the Uinta Mountains, but in the eastern half, where involved in the uplift of the Yampa Plateau, its line of outcrop has been carried by erosion well to the southward, away from the base of the range. In the region of Ashley Valley and Green River its outcrop and the outcrops of the Laramie and Montana pass in a sweeping curve around the ends of the older and harder Paleozoic and Mesozoic measures constituting the mountain proper and its immediate foothills. Farther to the east, in the region of Raven Park, by still another fold, in the southern face of the Yampa Plateau,

[1]Between the description here given and the outline of the Bridger formation on the special map, Pl. LX, a wide discrepancy exists. The map gives the results and conclusions of the Hayden Survey. In this text the delimitation of the Bridger is based upon the statements of Mr. J. B. Hatcher, of Princeton College, who has, with others, made a somewhat careful examination of the Eocene fauna of the Uinta Basin. In both cases the stratigraphy is the same, the only question being the horizon at which to place the line between the Green River and Bridger series.

now combined with a supplemental flexure in the Cretaceous and Tertiary beds immediately south of it, the outcrop of uplifted, southward-dipping Tertiaries is carried in the high Raven Ridge a distance of 15 or 20 miles to the south, to be regained in a northerly direction in the angle between the Yampa and White River plateaus. In the supplemental fold referred to the Laramie has a sharp, quaquaversal dip about a center of Montana, and possibly even of Colorado, shales.

Another quaquaversal, on the East Fork of Evacuation Creek, 5 or 10 miles above its confluence with the West Fork, presents a center of Wasatch, the Green River beds encircling it with lofty cliffs of the same general character as the Book Cliffs.

STRUCTURE.

The geological structure of the Uinta Basin has been quite fully set forth in what has already been said, but it is desirable to bring together under a single section the chief features. The basin is a syncline, with a major east-and-west axis about 170 miles in length, and a transverse north-and-south axis 75 to 100 miles long. The depression, except at the very rim on the northern and eastern sides, is gentle, with only occasional local crumples, the most important observed by the writer being the Split Mountain fold, the quaquaversal on the East Fork of Evacuation Creek, and the Raven Park fold. The fact that the entire Eocene series has been brought under the action of the forces causing the formation of the basin is evidence that the generation of the Uinta and Wasatch ranges and of the Yampa and White River plateaus was not completed till after the close of Eocene time.

Faulting of great importance occurred on the flanks of the high ranges bordering the basin on the north, east, and west, but in the development of the central portion of the basin no displacements greater than 8 or 10 feet seem to have occurred. On the southern slope of the Roan or Book Plateau, beyond the confines of the basin proper, a throw of 75 or 100 feet was observed by the writer in the vicinity of the mines of the Wasatch Asphaltum Company, northwest of Clear Creek Station. This was the maximum displacement found in the Tertiary area. Of the fractures in the center of the basin, it is a noticeable fact that all discovered have a lateral rather than a vertical displacement. In one or two localities slight displacement along a stratification plane has also been observed.

But if faulting with displacement is at a minimum, the basin is nevertheless the seat of a large number of most remarkable vertical cracks, now filled with uintaite (gilsonite), from one-sixteenth of an inch to 18 feet across, and in length from a few hundred yards to 8 or 10 miles. Their walls are smooth and regular, they show but the slightest undulation, and between the strata on opposite sides not even the slightest displacement can be detected. The cracks have a direction varying between N. 35° W. and N. 55° W., and except for an occasional short, sharp, transverse throw are peculiarly straight in trend. In some localities they appear to be approximately parallel with the strike of the strata and the trend of the main flexures in the ranges and their foothills; in others, they cut the strata diagonally to the strike. On this account there is not everywhere suggested a connection in their genesis with the broader structural folds. Again, none of the cracks shows the irregularities of fissures formed by the tearing asunder of strata along the axis of an anticline, nor are there the slickensides occasioned by the rubbing together of the walls in displacement. The termination of a crack, either in outcrop or vertically, is by the gradual approach of its two walls. An actual instance was observed in the Black Dragon vein on the West Fork of Evacuation Creek (fig. 31). From the nature of these cracks, however, the surface extent of a vein does not necessarily indicate its extent below the surface, for at a depth the fissure may continue far beyond its length of outcrop, or, on the contrary, may fall considerably short of this.

Figs. 27 and 30 also present another feature of common occurrence in veins of uintaite, namely, included fragments of country rock. These vary in size from a piece 2 inches across to one which might be regarded as locally splitting the vein in two. Occasionally separation from a wall is not complete, the fragment lying at an angle with it still attached—perhaps even to both walls (*d*, fig. 27). All the fragments observed by the writer were of the same material as the undisturbed stratum opposite which they were found, indicating that the distance traversed by them was slight.

It is not uncommon that from a fissure there spring one or more lateral cracks (*cc*, fig. 27), making with it a very acute angle, and at their points of departure from one fourth of an inch to 1 foot in width. They usually run to a point within a few feet, though the wider are somewhat the longer. These minor cracks show the same clean sides as do the main large fissures, the narrow portion of the rock between also being sharp of outline.

The origin of the cracks now filled with uintaite is, so far as our present knowledge avails us, still in doubt. They may have been produced in the gentle folding that took place in the formation of the Uinta Basin syncline, the strata being torn asunder from below upward instead of, as in an anticline, from above downward.[1]

A theory that has been suggested by Mr. Henry Wurtz[2] in explanation of a very similar crack, filled with grahamite, in West Virginia, is that it may possibly be a shrinkage fissure. But in the Uinta Basin, with the exception of an occasional warm spring, there are no especial evidences of former heat which, followed by cooling, might have served

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[1] For an instance of asphalt filling a crack along the axis of a gentle anticlinal fold (dip 4° and 14° on either side), see account of grahamite in the Hausteca, Mexico, by J. P. Kimball: Am. Jour. Sci. 3d series, Vol. XII, 1876, p. 282.

[2] On the grahamite of West Virginia and the new Colorado resinoid, by Henry Wurtz, of New York: Proc. Am Assoc. Adv. Sci., Vol. XVIII, 1869, p. 125.

to induce shrinkage. Of these two theories, therefore, the writer is inclined to the first, the origin from the gentle folding that produced on the broader scale the syncline itself, the strata not being sufficiently yielding to withstand even this comparatively small strain. If this is correct, the cracks may extend to a considerable depth, perhaps several thousand feet, and would have a tendency to widen in their descent, at least for a distance, unless occupied by rock masses squeezed in from the side.

DISTRIBUTION OF UINTAITE AND ALLIED HYDROCARBONS IN THE UTAH FIELD.

The area in which uintaite (gilsonite) and its associates of the hydrocarbon series, wurtzilite, elaterite, ozocerite, and maltha, the asphaltic limestones and sandstones, and a great series of bituminous shales are found lies in eastern Utah and just beyond in the western edge of Colorado. It is included between the meridians 108° 45′ and 111° 30′ W. and the parallels 39° and 40° 30′ N., in all perhaps 10,000 square miles, and is in the main coincident with the western half of the topographic depression known as the Uinta Basin.

Within this area uintaite (gilsonite) is, so far as at present discovered, confined to the Uncompahgre Indian Reservation and its immediate vicinity. The elaterite or wurtzilite deposits lie chiefly in the southern portion of the Uinta Reservation, only one or two localities being reported beyond its border. The ozocerite occurs in the vicinity of Soldier Summit, a station on the Rio Grande Western Railway, on the divide between the waters of Green River and those of the Utah and Salt Lake Valley. Maltha is reported at a number of isolated points within the area, notably in the divide between Spanish Fork and Strawberry Creek, 10 to 15 miles north of Soldier Summit, and in the region of Emma Park, northeast of Castle Gate. The asphaltic limestones thus far exploited occur in the southern spurs of the divide between Strawberry and Soldier creeks, about 7 miles northwest of Clear Creek Station (Tucker P. O.). The asphaltic sandstones outcrop in many of the valleys, notably the Ashley and Nine Mile; and the bituminous shales and limestones are broadly distributed.

THE VEINS.

APPEARANCE OF UINTAITE IN THE VEIN.

Uintaite (gilsonite) is a black, tarry-looking substance of most brilliant luster, normally of absolutely homogeneous texture, and exceedingly brittle. Its fracture is coarsely conchoidal. In mining it gives off a fine, chocolate-brown dust, most penetrating to skin and lungs. Sufficiently near the outcrop of the vein to be influenced by atmospheric agencies, it loses its brilliant luster for a dead-black surface, but a fresh fracture, no matter in how small a particle, shows its brilliancy still present, indicating a change to an inconsiderable depth only. Under atmospheric influences, also, uintaite shows a fine columnar structure at right angles to the walls of the vein and to a distance of about 6 inches from them. This structure has been recognized by Wurtz, Lesley, and others in grahamite, and by Lesley is called "pencillate." In addition to the columnar, there may be developed a cuboidal structure, in some instances by a further transverse separation of the pencillate rays; in others independent of these. In the upper 10 or 15 feet of a vein the latter structure not infrequently prevails through a

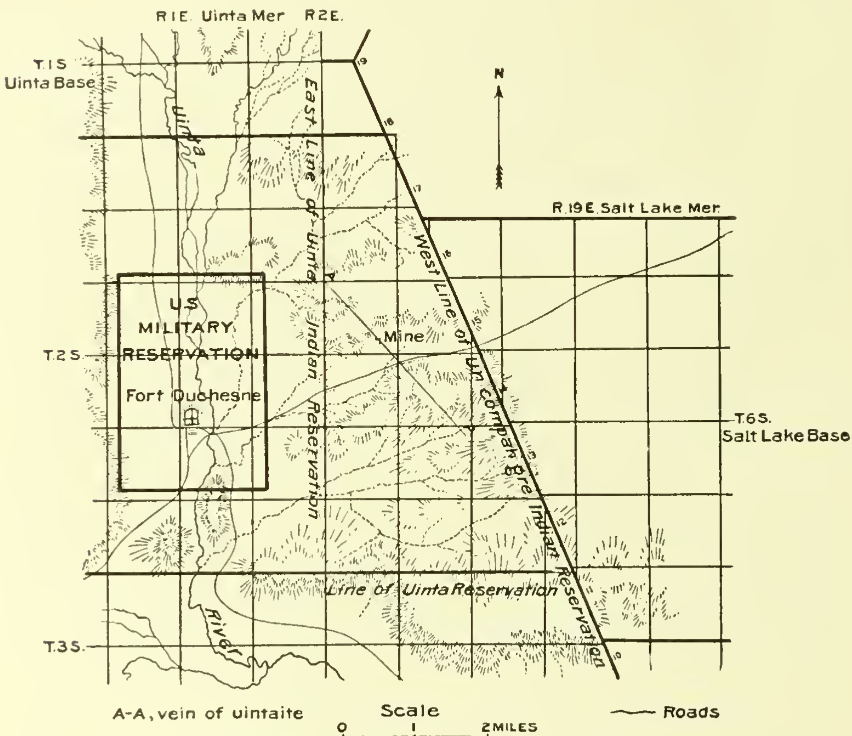


FIG. 26.—Sketch of region about Fort Duchesne, Utah.

large proportion of the uintaite, shading laterally into the two pencillate zones at the sides. It would seem quite probable that this structure, pencillate and cuboidal, is inherent in the material, having originated perhaps immediately after its injection into the fissure from cooling or from pressure.

The walls of the uintaite veins are usually impregnated with the mineral to depths of from 6 inches to 2 feet, though the shales, on account of their close texture, do not permit this to such a degree as the sandstones. The line between the impregnated and nonimpregnated portions of the wall rock is usually somewhat indefinite, but instances are not wanting of the sharpest demarcation.

LOCALITIES OF THE VEINS.

The region in which the uintaite (gilsonite) veins are found is the northern half of the Uncompahgre Indian Reservation, extending slightly beyond its borders both on the east and west, in the former direction 4 or 5 miles into Colorado. The larger veins are somewhat scattered, one lying about 3½ miles due east of Fort Duchesne, a second in the region of Upper Evacuation Creek, and the three others of chief importance in the vicinity of White River and the Colorado-Utah line. Besides these, there is a 14-inch vein crossing the western boundary of the reservation in the vicinity of the fortieth parallel; another of equal size about 6 miles southeast of the junction of the Green and White rivers; a third in a gulch 4 or 5 miles northwest of Ouray Agency, west of the Duchesne River; and a number from one-sixteenth of an inch to 1 foot in thickness in an area about 10 miles wide extending from Willow Creek eastward for 25 miles along both sides of the Green and White rivers. The locations of these veins are all shown on the general map of the Uinta Basin (Pl. LIX).

FIG. 27.—Diagram showing the several features of the Duchesne vein in place. Not drawn to scale. *a*, Included fragment of sandstone. *bb*, Fault. *cc*, Lateral cracks. *d*, Cross course of sandstone. *e*, Country.

THE DUCHESNE VEIN.

For convenience, the vein lying 3 miles east of Fort Dechesne may be designated by the same name as the post. This vein has been worked for several years and is opened to a depth of 105 feet, but at the time of the writer's visit was accessible only to a level 65 feet beneath the surface. The superficial strata are of the Uinta formation, and consist of heavy bedded sandstones and shales having a gentle northward dip of 5° to 10°. The manner in which the uintaite occurs and its appearance in the fissure are the same as given above for the veins in general.

The vein is vertical and has a N. 40° W. trend. It is traceable for about 3 miles. A width of from 3 to 4 feet is maintained for a length of about 1½ miles along the middle of the outcrop, but beyond this, in either direction, it gradually diminishes to complete disappearance. The Duchesne vein shows an occasional short transverse fault (*bb*, fig. 27), the planes of which may differ in trend and dip, but in the two or three instances observed by the writer were inclined to the eastward 75° or 80° with the horizon. The throws, none over 8 inches, cause little disturbance to the vein other than a direct crack across the filling. Near the northern end of the present workings, in a surface trench, the vein displays several included fragments of wall rock completely surrounded by asphaltic material (*bb*, fig. 28). Another feature, perhaps of especial significance in the origin of these veins, is the diagonal course of country rock (*d*, fig. 27), dividing the vein in two at a level near the present surface of the ground. It is quite probable that this diagonal course of sandstone will disappear in depth and the vein then become continuous. This is apparently an instance of a rent in which the crack was interrupted by a fragment of rock which was not wholly severed from either wall in the rending. The walls of the Duchesne vein are well defined, though their planes wave slightly both on the trend and in depth. Several openings, surface cuts and shafts, have been made, which show the character of the deposit for nearly its entire length.

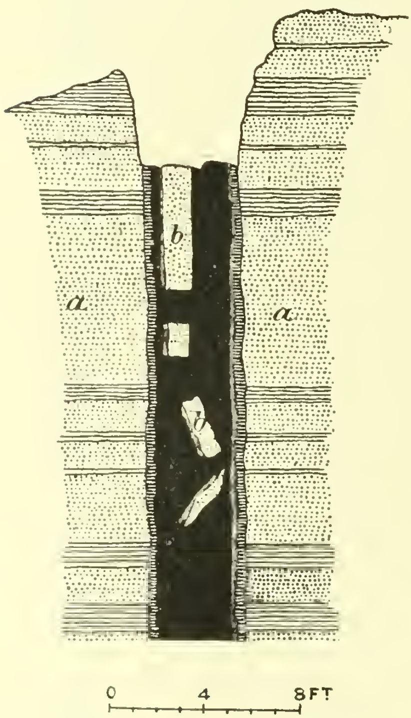


FIG. 28.—Cross section, Duchesne vein. *a a*, Country. *b b*, Fragments of wall rock.

The St. Louis Gilson Asphaltum Company controls the greater part of the vein, and has shipped a comparatively large amount of gilsonite in the five or six years in which it has been operating. The product, according to its even, homogeneous texture and massive character, or its cuboidal or pencillate structure and crumling tendency, indicative of alteration from atmospheric influences, is divided into first and second grades, used in the trade for different purposes or for the manufacture of different qualities of the same article.

THE CULMER AND SEABOLDT VEINS.

The Culmer and Seaboldt veins, of 14 and 12 inches maximum width, respectively, cross the western edge of the Uncompahgre Reservation in the vicinity of the fortieth parallel. The veins are parallel, the Seaboldt east of the Culmer about 100 feet. Their general trend is N. 35° W., and they have a westward dip of from 85° to 88°. Only the Culmer is workable, and this at great disadvantage.

The outcrop of the Culmer vein has been prospected for a distance of about 2 miles from its northern end, but it is said that it may be followed southward 2 or 3 miles farther, showing for this portion, however, diminished width. The Seaboldt vein has received less attention, but so far as known is hardly of a thickness to warrant development. The superficial rock of the region is gray, green, and purple sandstone and shale, probably of the Washakie or Bridger formation. The strata strike west-northwest and dip about 5° NNE.

In their general character the Culmer and Seaboldt veins resemble the Duchesne. The uintaite shows the same homogeneity of texture remote from atmospheric influences, and near the outcrop the columnar, pencillate, and cuboidal structure. Fragments of the country rock are found in it, and thin lateral cracks, filled with gilsonite, are given off from its sides at angles very acute. The compactness of the Culmer vein is maintained for the entire length exploited, but the Seaboldt, while a single body of about 12 inches at the northern exposures, to the south is split in two by 12 to 16 inches of rock. Whether these branches again unite in the covered region beyond is undetermined.

The Culmer vein shows a number of nearly vertical, transverse faults at short intervals, with offsets from 1 to 6 feet each, the portion of the vein south of the fractures always being carried west. Neither vein nor adjoining country rock seems to have suffered especially marked fracturing in these displacements. Besides the above faults, there is one (fig. 29), to be observed at several points along the vein about 8 feet below the surface, of which the plane has a northeast dip of about 8°. The strata above the fracture have usually been moved upward along the fault plane from 6 to 12 inches. Occasionally a throw in the opposite direction is encountered, though whether on the same plane as the foregoing was not clear.

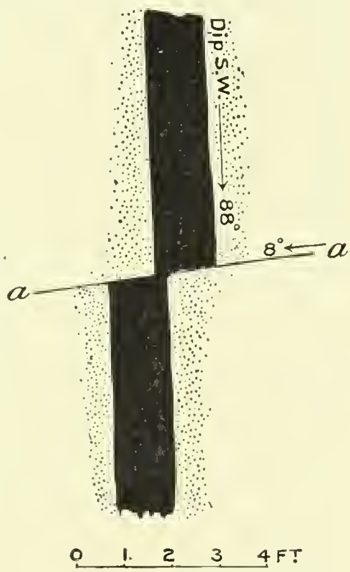


FIG. 29.—Cross section, Culmer vein. a—a, Fault.

The product of the Culmer mine is separated into first and second grade on the same basis as at the Duchesne. On account of the narrowness of the vein, especial care is used in mining not to deteriorate the higher-class material by sand from the walls or by admixture with it of the more weathered portion of the gilsonite. The second-grade material is sometimes thrown over a coarse sieve or screen, by which some of the dirt is removed and the quality thus improved.

The water from the mine is strongly mineralized, rendering it highly unpalatable.

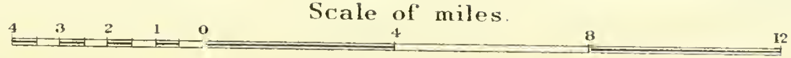
THE BONANZA AND COWBOY GROUP.

(PLATE LX.)

The most important locality of uintaite (gilsonite) is the region immediately north and south of White River near the eastern edge of the Uncompahgre Reservation. Here are three parallel vertical veins of constant N. 55° W. trend, cutting the sandstones of the Bridger formation and doubtless extending into the shales of the Green River below. The strata dip to the northward and the fissures do not seem wholly to have taken the line of strike of the beds, but rather a direction somewhat diagonal to this. The veins are known as the Little Bonanza, the Big Bonanza, and the Cowboy, but the two Bonanzas had best be known as the West and East, respectively, for at some points the Little Bonanza attains a greater size than the Big Bonanza. The Little Bonanza is the southwestern of the three, lying about 500 feet from the East or Big Bonanza, while from the Cowboy the latter is distant about 2½ miles. None of these veins is exploited, only a shallow prospect appearing here and there. In general features and in character of filling they are like the Duchesne and Culmer veins; the cracks are doubtless of similar origin, and the material occupying them is unquestionably derived from the same ultimate source as that in the others. The structure of the uintaite is also the same—that is, it is primarily massive, but in the outcrop is pencillate next to the walls and cuboidal elsewhere; the brilliant luster, too, is replaced in the outcrop, except on a fresh fracture, by the dull black of a surface long exposed. So far as at present known, the greatest widths of the veins are attained north of White River, to the south being reported considerably less or the vein as having never been discovered.

North of the river both the West (Little) and East (Big) Bonanzas may be traced from the canyon slopes northwestward a distance of fully 3 miles. They vary considerably in width within this length, but both are probably of workable thickness at all points. Near the summit of the ridge extending along the White River canyon on the north, the West or Little Bonanza attains a maximum observed width of 10 feet 6 inches, but the greater part of the vein to the northwest shows a width somewhat less, perhaps an average of 4 to 5 feet. The Big or East Bonanza, in the crest of the ridge just mentioned, is but 7 feet 6 inches wide, attaining its maximum observed width, 13 feet 6 inches, in a little hill about a mile north, just east of the road leading from Coyote Basin to Wagon Ax. Both Bonanzas cross this road, and are easily traceable to another hill a mile northwest, where they again appear in prominent exposures. The East Bonanza is here about 8 feet wide, the West still of workable thickness. Northwest from this hill their outcrop is clearly discernible for a distance of between 1 and 2 miles, the broad swath of scant vegetation which everywhere marks the presence of the veins being a conspicuous feature of the scene. South of White

Scale of miles.



Contour Interval 200 feet.

MAP OF THE WHITE RIVER UINTAITE (GILSONITE) REGION

QUATERNARY	TERTIARY				CRETACEOUS				JURA TRIAS			
Alluvium	Uinta	Bridger	Green River	Wahsatch	Laramie	Fox Hills	Colorado	Dakota Group	Jurassic? Variegated Beds etc	Red Beds etc	Upper Carboniferous	Middle Carboniferous
A	U	Br	GR	W	L	F	C	Dk	J	T	UC	MC
						Fox Hills Fort Pierre	Niobrara Fort Benton					

Scale of miles

4 3 2 1 0 4 8 12

Contour Interval 200 feet

River, Mr. McAndrews, of the Ouray Agency, states that he has traced both Bonanza veins quite to the Colorado line, but that along this portion of their length they become much thinner. In Colorado the single vein discovered is said to be on the trend of one or the other of the Bonanzas, and may prove to be either its continuation or another vein originating in an independent crack belonging to the same system. The Colorado vein has a length of nearly 2 miles east of the interstate line, and has been prospected for this distance and at one or two points worked in a small way to a depth of 100 feet. It has a general width of about 3 feet.

The Cowboy is the largest of the three veins in the White River region, a maximum width of 18 feet having been observed at the crest of the ridge a mile north of the river. In either direction from this point it thins considerably, but maintains a width of 10 to 12 feet for a distance of at least 2 or 3 miles. Northward its presence is indicated beneath the wash of Coyote Basin, just as the road turns for Wagon Ax, by the heavy occurrence of gilsonite particles, both in the wash and in ant-hills formed of it. This point is immediately north of a prominent hat-shaped butte, and is between 4 and 5 miles northwest of the point where the vein crossed the ridge north of White River. On the southern face of this ridge, across its benches, and in the walls of side canyons, the vein is easily traced by swath and outcrop to the immediate bluffs of the river, where it is lost in the talus of shale. South of White River it is said not to have been discovered, but from the nature of the formations its outcrop might easily be concealed in their débris, and it should be considered as wanting only after careful prospecting.

The topography of this region is that of a high body of land cut to a depth of 1,000 or 2,000 feet by the narrow gorge of White River, the elevated region south of the stream being deeply indented with lateral canyons and excessively rugged; that north but slightly indented, and presenting at its top a broad area of rolling hills upon an otherwise flat table. The region north of White River is therefore of a nature to render the veins easy of access and readily worked, except for water, which would have to be raised mechanically from the river, and for fuel, which in a short time at furthest could be obtained only at a distance of 15 to 50 miles. Any settlement would for convenience be located in the narrow bottom along the stream. From the river canyon any of the veins could probably be reached by tunnel at comparatively slight expense, while shafts would be required on the plateau. But as the plateau north of the river would doubtless be the location of a railroad, rather than the almost impassable canyon with its crumbling walls, the shaft method would, for this portion of the field at least, be adopted, tunnels being used for drainage only. South of the river, on account of conditions of transportation as well as of water, mining could be prosecuted only at a disadvantage compared with operations on the north side.

The openings in Colorado are located on the crest and eastern slope of the ridge dividing Evacuation Creek from the waters running directly into White River and the streams farther east. They are at present reached by road from Rifle to Meeker, thence down White River to Dripping Rock, a few miles east of the interstate boundary, and from here by a specially constructed road up a tributary to the south 9 miles, a total of 125 miles from Rifle.

THE BLACK DRAGON VEIN.

The Black Dragon vein is located in the region of Upper Evacuation Creek. The southern end of its outcrop is in a canyon tributary to that of the West Fork of the creek, the first of importance above the confluence of the latter with the East Fork, a distance of about a mile. From this point, which is within a half mile of the Colorado line, the vein was traced by the writer nearly a mile well toward the summit of the ridge separating Evacuation and Asphalt creeks, and it is said by Mr. McAndrews to extend into some of the upper tributaries of the latter stream, in all a distance of 3 or 4 miles from its southern end, maintaining for the entire way a workable thickness, though somewhat thinner than the exposure in the tributary of the West Fork of Evacuation Creek. Considerable prospecting has been done on the vein near its southern end, and the largest cut shows a clean breast of uintaite 8 feet 6 inches across. The walls are vertical, and whether of sandstone, limestone, or shale, are impregnated with the asphalt from 1 to 3 feet from the vein. The columnar, or pencillate, structure is developed in the asphalt to a depth of 6 inches from either side; the center, the remaining 7 feet, except at the very surface, showing the usual structureless, homogeneous mass, of coarsely conchoidal fracture and brilliant black luster. At a prospect a few hundred feet above the main opening on the vein the conditions shown in fig. 30 were found. The horse (*bb*), 2 feet of sandstone, evidently derived from the wall opposite, was, like it, completely impregnated with the uintaite, which showed on a minute scale the same physical properties, fracture, etc., as the material in mass. The vein here also shows a sharp horizontal displacement (*cc*) of 8 inches, the portion above having moved to the

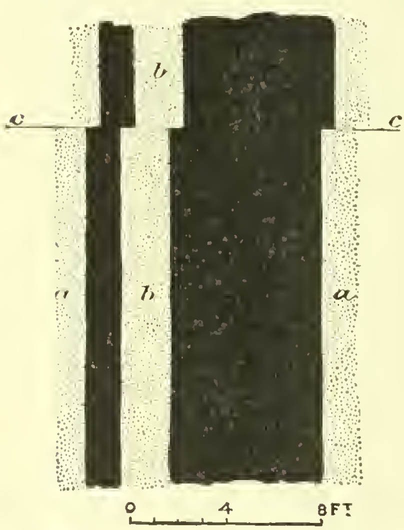


FIG. 30.—Cross section, Black Dragon vein, Evacuation Creek, upper prospect. *aa*, Country. *bb*, Horse. *cc*, Fault.

northeast. Although somewhat concealed from view at the line of fracture, the vein seemed to afford in the more exposed portions but little evidence of actual crushing. On the southern side of the gulch in which the foregoing observations were made, within 150 or 200 yards of the openings referred to above, the very southern end of the vein, at least at the outcrop, shows in a low cliff of sandstone precisely as sketched in fig. 31. From its appearance it gives evidence of continuing in depth beyond this point, the apex of the vein sinking to the southeast.

The vein has an approximately N. 55° to 60° W. trend, is vertical, and cuts the lower portion of the Green River beds, sandstones, shales, and limestones, among the latter being some fine types of oolitic structure, so characteristic of the lower part of this formation. In passing through these several beds, different as they are in texture, the walls of the crack seem to have been but little disturbed in their regularity, presenting everywhere an almost perfect plane. The strike of the beds is here approximately northeast-southwest, the dip 5° NW. The position of the vein is advantageous to economical working, in that a drift from the bottom of the valley where exposed would pass at least 700 to 1,000 feet below its highest point of outcrop. Timber is more convenient here than at points on White River, but water is in minimum quantity.

Fig. 31.—Terminal cross section at outcrop of Black Dragon vein, Evacuation Creek. *aa*, Country. *bb*, Fragments of wall rock.

In the same cliff in which is exposed the section of the southern end of the Black Dragon vein, and parallel with the latter in strike and dip, are two bodies of dark-gray sandstone that would at first sight be taken for vertical dikes in the lighter-gray sandstone of the cliff. Fig. 32 represents one of these bodies. They prove, however, on close examination, to be simple zones of the ordinary sandstone, impregnated with uintaite to a remarkably uniform distance on either side of a median crack now tightly closed, but with a thin film of the asphaltic mineral here and there along it. The total width of each zone is 18 inches, one-half on each side of the median crack. The distance between the zones is 9 feet, and the eastern one is also 9 feet from the uintaite vein. These impregnated bodies pass upward beyond the end of the vein of uintaite, but they were not traced out. The precise manner in which their impregnation took place is difficult to surmise. The median crack would seem to indicate at least a possibility of its having once been opened, furnishing a channel for the asphaltic material, and then closed, the uintaite passing into the walls to a surprisingly regular depth. Evidence that such is the case exists in the lateral continuation of the laminæ composing the heavy bed of sandstone from the unimpregnated portion to the impregnated, even plant impressions, which occur in quantities between the layers, being found half in the impregnated and half in the unimpregnated part without interruption in continuity.

CONDITIONS OF IMPREGNATION.

The condition in which the gilsonite found its way into the veins seems most probably to have been that of a plastic mass, coming from below under pressure, and, although of high viscosity, sufficiently fluid to be pressed between the grains constituting the wall rocks, whether of sandstone, shale, or limestone. As to the fragments of country rock in the veins, it is to be remarked that they are often entirely free from the walls, surrounded with uintaite. They are heavy, and, but for a supporting medium, when torn from the walls must have fallen to the bottom of the crack, or at least lodged at points far below their original position. They would hardly have been carried to the very apex of the fissure, as seen in the section of the southern end of the Black Dragon vein. It would seem, therefore, that in the formation of a fissure it must have been almost instantly filled with the plastic asphalt, and that the pieces of wall rock, more or less separated from the sides, hanging by mere threads, as it were, were caught in the rising current of uintaite and so carried a short distance from their original places. The larger fragments, the horses, which also occupy positions isolated from the walls, it is difficult to conceive as acquiring their position in any other way than that suggested, and it must be due to the rapidity with which the asphalt hardened, as well as to its viscosity, that they did not sink to the bottom in a medium which is so different in specific gravity.

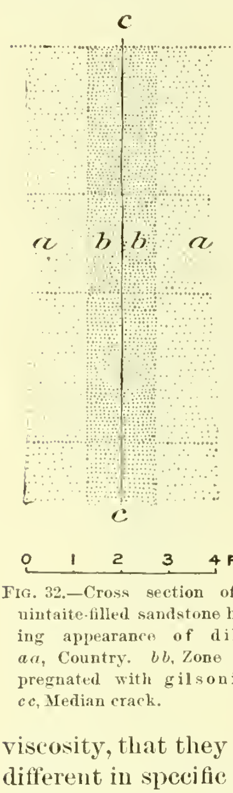


FIG. 32.—Cross section of a uintaite-filled sandstone having appearance of dike. *aa*, Country. *bb*, Zone impregnated with gilsonite. *cc*, Median crack.

The writer frankly confesses his lack of ability to suggest the conditions under which the uintaite (gilsonite) existed prior to its flow into the cracks.

THE COMPARATIVE OCCURRENCE OF RELATED HYDROCARBONS.

Grahamite and albertite, the hydrocarbons closely related in chemical constitution to uintaite (gilsonite), occur also in very much the same way. This is especially the case with grahamite, as shown in the two localities where it has been studied, namely, in Ritchie County, W. Va., about 20 miles southeast of Parkersburg, and in the Huasteca, in the northwestern portion of the State of Vera Cruz, Mexico. Albertite is also reported with the grahamite in the same Mexican locality, but the best-known occurrence is in the Province of New Brunswick, where the mineral fills a crack of displacement along the axis of an anticline.

Dr. Henry Wurtz has published an account of his examination of the West Virginia vein,[1] a summary of which follows:

The structure shows four distinct, though somewhat irregular, divisional planes, having a general parallelism with the walls. Next to the walls the structure of the mineral is coarsely granular, with an irregularly cuboidal jointed cleavage, very lustrous on the cleavage surfaces; that in immediate contact with the walls usually adhering thereto very tenaciously, as if *fused* fast to the granular sandstone.

Next these two outside layers, which are very irregular and from 2 to 3 inches or more in thickness, is found, on each side of the vein, a layer averaging from 15 to 16 inches in thickness, which is composed of a variety highly columnar in structure and very lustrous in fracture, the columns being long and at this place at right angles to the walls. It is this variety that was given to Professor Lesley, as would appear from his description. Finally, in the center of the vein, varying in thickness but averaging about 18 inches, is a mass differing greatly in aspect from the rest, being more compact and massive, much less lustrous in fracture, and with the columnar structure much less developed, in places not at all. The fracture and luster of this portion of the vein are clearly *resinoid* in character.

The general aspect of the mass, as well as all the results of a minute examination of the accompanying phenomena, lead irresistibly to the conclusion that we have here a fissure which has been filled by an exudation, in a pasty condition, of a resinoid substance derived from or formed by some metamorphosis of unknown fossil matter contained in deep-seated strata intersected by the fissure or dike. It is not necessary to suppose a degree of fluidity greater than that of semifused pitch or inspissated tar. Such a soft doughy mass, though flowing but slowly, would *in time* be forced by a very moderate pressure into every portion and into every crevice of the fissure. The peculiar structure described is such as would result from the fissuring of a fused or semifused viscous mass by the refrigeration produced by contact with the cold, and, it may be, wet walls of the fissure; the outside granular layers being due to rapid cooling, and the columnar fracturing at right angles (or nearly so) to the walls (as, for example, in the case of a dike of columnar basalt) to a more gradual reduction of temperature, connected, without doubt, with the well-known tendency of such materials as are susceptible of the vitreous or viscous fusion to assume in time a concretionary or nodular structure. This tendency is strongly apparent in the brilliant variety, having produced multitudes of those curious markings on fissured surfaces which were mistaken in the case of the albertite for *fossil impressions*. The transverse columnar structure is called by Lesley "pencil cleavage."

Toward the extremities of the outcrop, where the sheet of mineral is thinner, this pencillate structure extends throughout the mass.

In sinking a small shaft here, 28 feet deep, Mr. J. Carville Stovin, the engineer in charge at the time, found a detached fragment 3½ feet long of the north wall of the dike embedded in the mineral 24 inches distant from said wall and 29 inches vertically below the *hiatus* in the wall, marking its point of detachment; while exact measurements, both of itself and of the cavity left (on removing the mineral which occupied its original space) showed that it had become entirely inverted in position during its descent. The pitch-like semifluidity which I have contended for is here strongly illustrated by the small depth of descent of this mass of quartzose sandstone through a material whose density could not have been half of its own; while its distance from the wall and inverted position suggest that at the time of its

[1] On the grahamite of West Virginia and the New Colorado resinoid: Proc. Am. Assoc. Adv. Sci. for 1869, Vol. XVIII, p. 124.

detachment the dough-like mass was still rising, or in some sort of motion at least, in the dike fissure.

I myself observed similar *horses* of the wall rock, of small size, similarly embedded in the mineral at several points.

The horizontal extent of visible outcrop actually measured by me was 530 fathoms, thinned out at east end to 30 inches and at west end to 8 inches; but as these points were at least 70 to 80 fathoms vertically higher than the bottom of the ravine, the width (averaging about 50 inches) at the latter depth points to a rapid widening of the fissure in descent.

The occurrence of grahamite at the Cristo mine, in the Huasteca, Vera Cruz, Mexico, has been described by Dr. J. P. Kimball.[1] Following is a summary:

The deposit consists of two continuous parts, the one occupying a nearly vertical fissure traversing the fossiliferous shales and the other part conformably overlying these shales, which are slightly inclined. We have here the phenomena, first, of a deep-seated fissure transverse to the bedding of the formation and filled out with grahamite; and second, a nearly horizontal and originally superficial deposit of the same material overspreading the shale formation for a limited distance from the fissure. The latter occurrence is an overflow from the fissure, and, as it lies between the two formations, is to be referred to a period subsequent to the deposition of the shales and before the conglomerate was spread upon them in the form of pebbly detritus. It thus happened when the shales formed the surface at this point, just as asphaltum is now commonly formed upon the surface, as a residuum from the evaporation and oxidation of liquid or pasty malthas issuing from sluggish springs or oozing from more extended sources, as from a certain stratum or rift in the rocks.

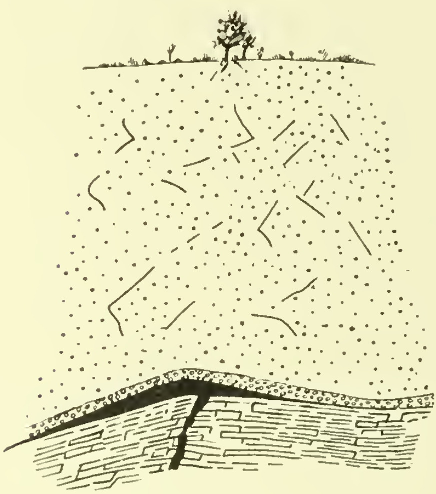


FIG. 33.—Section grahamite vein, in the Huasteca, Mexico.

The vein occupying the fissure has a columnar structure transverse to its sides and shrinkage partings or joints parallel to its sides. It has thus far proved remarkably homogeneous in structure and free from admixture of rock or clay. Its dip is 64° to the west. Near the point where it passes out of sight under the river bed it is joined at an acute angle by a narrower and tapering vein, of which the maximum width is 9 inches.

The fissure occupies the axis of a gentle anticlinal, with a dip of 14° W. on the west side and of 4° E. on the opposite side. As the overflow conforms to the steeper dip, it appears that the fissure must have been made at the time of the elevation of the shales, and soon afterwards filled with asphaltum, which continued to form after it had been filled. That no great period was required for this operation is shown by the fact that the overlying conglomerate also conforms to the stratification of the shales as well as to the outline of the overflow of the grahamite locally intervening

The occurrence of such a fissure in shales, so imperfectly hardened and so easily

[1] Am. Jour. Sci., 3d series, Vol. XII, 1876, p. 277.

weathered, affords another proof that the filling of the fissure immediately followed its formation—that is, after the emergence of the shales and before the deposition of the overlying alluvium.

Concerning the source of the filling of this fissure, the grahamite, Dr. Kimball remarks:

The sandstone formation is the source of a number of deposits of chapapote or asphaltum. Numerous deposits are said to occur north of the Panuco River. One deposit which I visited is found on the Tanelul ranch, occupying an elevated basin or cul-de-sac between two hills of the Alacranes range, here forming the boundary of the Capadero Valley. The point is some 2½ leagues east of the Cristo mine, and directly in range with the course of the Cristo fissure as far as traced. The chapapote has accumulated from the evaporation of liquid maltha, which now issues in the form of a sluggish spring, with a number of orifices. Here may be witnessed the same process by which the above-described overflow of the Cristo mine was originally formed. The source of the chapapote spring is the sandstone above mentioned, on which rest the grahamite-bearing shales of the valley below. It thus appears that the uplifted portions of the underlying sandstone are at present the source of chapapote springs depositing that mineral substance upon the surface. Ancient, and perhaps more copious, springs of the same kind issued from the depressed portions of this formation and forced their liquid maltha into the fissures and lesser interstices of the overlying shale, which, as I have already stated, is remarkably cleavable and imperfectly indurated. The tendency of such a body of shale or shaly clay, exceedingly fine in texture, to form shrinkage and cleavage partings is well known. Hence this formation, from its nature otherwise impervious, became the permanent receptacle of maltha or asphaltic petroleum issuing from the sandstone below; and probably the more freely under a hydrostatic pressure, in which water played a part, and the action of which is strikingly suggested by the configuration here observed of a stratigraphical basin bordered by elevated plateaus. The inspissation of maltha or pittasphalt, and even petroleum, to grahamite and other mineral bitumens, by the loss of hydrogen and the addition of oxygen, is a well-known occurrence which may be artificially illustrated in the laboratory.[1] While asphaltum is observed to be the product of the immediate evaporation and oxidation of maltha at or near the surface, a slower and continued oxidation beneath the surface—in fissures, cavities, and interstices of the rocks—has produced grahamite, albertite, and other less hydrogenous hydrocarbons of the same type.

Dr. Kimball also mentions the fact that—

Smaller exhibitions of grahamite in the shale of the river banks at Tempoal and the Aguacates are of the same general nature as the deposit of the Cristo mine. They occupy interstices between divisional planes of the formation, thus forming veinlets which often pass from between one kind of partings to another. Hence even the larger of these deposits or pockets are very capricious in position, while the smaller ones merely reticulate the rock. They seem to have no connection or channels.

The occurrence of albertite at Hillsborough, New Brunswick, has been described by Prof. C. H. Hitchcock.[2] From the article the following extracts have been made:

The rocks are of Lower Carboniferous age and belong to the Acadian coal series. The lowest rock in the Carboniferous series is the Albert shale. This shale contains

[1] W. P. Jenny: Am. Chem., Vol. V, p. 10.

[2] The Albert coal, or albertite of New Brunswick: Am. Jour. Sci., 2d series, Vol. XXXIX, 1865, p. 267.

a large amount of hydrocarbonaceous matter. Certain layers of it at the Caledonia Oil Works, by a rude process, have yielded 30 gallons of refined illuminating oil to the ton. The greater portion of the shale will sustain a fire without the aid of other fuel. It contains immense numbers of fossil fish, almost enough to make one imagine they gave the shale its inflammable character. This series can not be less than 1,000 feet thick.

The second group of strata is a conglomerate, separated from the first by a narrow bed of sandstone. Bits of Albert coal and shale constitute component parts of certain coarse sedimentary strata of this group and render them oleaginous. The thickness is unknown, probably from 100 to 200 feet.

There appears to be an anticlinal axis passing through this region trending nearly 10° north of east.

There appears also to be a fault along or near this axis, displaying the usual phenomena of anticlinal fissures, and its location may easily be accounted for. The shale was not strong enough to sustain the bending; hence its layers were much twisted and fissured along a central line.

The coal (albertite) shows the effects of the crushing process no less plainly. It is much broken, even to grains, and needs no pick for its removal from the vein. It will flow as easily as heaps of corn, and therefore pains are taken to tap the vein in the right place and at the proper time. If by oversight the main shaft is not walled up very tight, the coal will stream through the crevices between the beams, to the great inconvenience of the workmen.

The general course of the vein is N. 65° E., but the coal (albertite) is repeatedly heaved southward by small faults. Its inclination is northwestward from 75° to 80°, often vertical. The body of the vein is extremely irregular, constantly expanding and contracting, both laterally and vertically. What is too narrow to be worked in one level enlarges to 6 and 12 feet a hundred feet lower, or the reverse; but in general the width increases in following down the vein. At the time of Percival's examination the vein was not considered workable 170 feet west from the old shaft. At lower levels the yield is remunerative 700 feet west and 2,300 feet east of the new shaft, which lies several rods west of the first. Whenever a displacement is met with the vein is not lost, because a film of the coal remains in the slip to indicate the location of the heaved portion. The widest part of the vein is said to be 28 feet.

The narrow portions of the coal are invariably contained in a harder rock; where the rock is softer the vein is larger. "Horses" are common. In such cases the cavity above, out of which the horse fell, is found to be filled with coal; so that the width of the coal at that level is equal to the usual width plus the width of the horse. Numerous small branches run off into the shales from the main vein. These are short and might be described as irregular and branching spines from a main stem.

The vein character of the deposit is seen more distinctly in the smaller openings. On the East Albert property two shafts have been commenced near the anticlinal line in the conglomerate over the shale. These reveal, at the depth of 30 feet, nearly 6 inches width of a richer and more beautiful coal than the Albert, gradually thinning out to the width of coarse paper at the surface, and most unequivocally cutting vertically across nearly horizontal layers of sandstone.

In addition to the foregoing, there is an extended statement by Dawson in his Acadian Geology for 1868, page 231; and other writers also have discussed from time to time the occurrence of this series of minerals.

Comparison of the foregoing descriptions shows that there is a remarkable similarity in the manner of occurrence of all three of the hydrocarbon compounds known as the asphaltites—equal, indeed, to their resemblance in chemical composition.

ESTIMATED TONNAGE OF THE UINTAITE FIELDS OF UTAH.

Following is an estimate of the amount of uintaite (gilsonite) in the six veins of workable thickness that have been described in the foregoing pages. The figures must be taken with allowance, for in the unexploited condition of the veins it is impossible to deduce laws of occurrence in depth or in width; neither has the outcrop been prospected in detail, and the lengths given are therefore somewhat uncertain. Table V is a general estimate for veins of uintaite of definite dimension, the figures of which have been employed in computing the contents of the veins in the field under discussion.

TABLE V.—*Tonnage contents of gilsonite veins for a depth of 1,000 feet, but of varying widths and lengths.*[1]

Width of vein.	Length of 1 mile.	Length of 2 miles.	Length of 3 miles.	Length of 4 miles.	Length of 5 miles.
Feet.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
1	176, 000	352, 000	528, 000	704, 000	880, 000
2	352, 000	704, 000	1, 056, 000	1, 408, 000	1, 760, 000
3	528, 000	1, 056, 000	1, 584, 000	2, 112, 000	2, 640, 000
4	704, 000	1, 408, 000	2, 112, 000	2, 816, 000	3, 520, 000
5	880, 000	1, 760, 000	2, 640, 000	3, 520, 000	4, 400, 000
6	1, 056, 000	2, 112, 000	3, 168, 000	4, 224, 000	5, 280, 000
7	1, 232, 000	2, 464, 000	3, 696, 000	4, 928, 000	6, 160, 000
8	1, 408, 000	2, 816, 000	4, 224, 000	5, 632, 000	7, 040, 000
9	1, 584, 000	3, 168, 000	4, 752, 000	6, 336, 000	7, 920, 000
10	1, 760, 000	3, 520, 000	5, 280, 000	7, 040, 000	8, 800, 000

A rough estimate of the contents of the Duchesne vein—including the product already mined—based on observations along the outcrop, and for a depth of 1,000 feet, shows the amount of uintaite (gilsonite) to be a little less than 1,000,000 tons. The details of the measurement, with the tonnage, are:

Contents of the Duchesne vein.

	Average width of vein.	Yield in 1,000 feet depth.
	Feet.	*Tons.*
For about 660 feet from the northwest end of the vein	$1\frac{2}{3}$	36, 666
For next 300 feet southeast, about	$2\frac{1}{4}$	22, 500
For next 2,970 feet southeast, about	$3\frac{1}{3}$	330, 000
For next 3,960 feet southeast, about	3	396, 000
For next 2,970 feet southeast, about	$1\frac{7}{12}$	156, 750
		911, 916

[1] Specific gravity of gilsonite, average of several authorities, 1.07. Weight of cubic foot of gilsonite, 66.875 pounds. Number of cubic feet in 1 ton, 29.9 (taken at 30 in table).

The outcrop then shows a width less than will allow profitable working.

The Culmer vein may average 15 inches in width for a distance of 2 miles—possibly farther. For a length of 2 miles and a depth of 1,000 feet it would yield 410,666 tons. But such a depth will never be attained in working this small vein. In view of the larger veins, but little less accessible, it is doubtful if the 100-foot level is ever passed.

The Little or West Bonanza attains a maximum observed width of 10 feet 6 inches, but for the 3 miles north of White River the average width would perhaps be 5 feet. This, for a depth of 1,000 feet, would give a content of 2,640,000 tons. An additional width of 4 feet for 1 mile, which is quite probable from the outcrop traversed, will increase the foregoing to 3,344,000 tons.

The Big or East Bonanza, for that portion north of White River, fully 3 miles, maintains a general width of 10 feet, and has therefore a content to a depth of 1,000 feet of 5,280,000 tons.

South of White River both the Little and Big Bonanza veins have been traced nearly or quite to the Colorado line, and one of them, or a distinct vein on their trend projected, is said to extend for nearly 2 miles into Colorado, with an average thickness of at least 2 feet 6 inches. For the distance between the White River and the Colorado line—2 miles—it would seem quite possible, from statements of Mr. McAndrews as to the width of the veins, that the two Bonanzas would be capable at a conservative estimate of a yield of at least 1,000,000 tons, and for the vein in Colorado a product of 880,000 tons would be afforded to a depth of 1,000 feet. These estimates would bring the total yield of the two Bonanza veins for their entire length, including the Colorado portion, to 10,504,000 tons.

The Cowboy vein is the largest of all, and for at least 2 of the 5 miles over which it can be traced has an average width of 12 feet, for a half mile attaining 16 or 18 feet. Over the remainder of its length 8 feet is believed a safe estimate. These dimensions to a depth of 1,000 feet will yield 8,888,000 tons of uintaite.

The Black Dragon vein, on Upper Evacuation Creek, will perhaps average 6 feet for 2 miles, and for this portion of it would afford a product of 2,112,000 tons. It is reported as extending 2 or 3 miles beyond the limit for which this estimate is made, which, if true, would increase this amount to at least 3,000,000 tons.

The total yield of the six uintaite veins referred to above, accepting the foregoing figures as approximately correct, would amount to 23,744,582 tons.

TABLE VI.—*Summary of tonnage contents of uintaite veins.*

Vein.	Tons.
Duchesne	941,916
Culmer	410,666
Bonanzas	10,504,000
Cowboy	8,888,000
Black Dragon	3,000,000
Total	23,744,582

THE EXPLOITATION OF THE UINTAITE (GILSONITE) VEINS.

Mining for uintaite will be conducted after the ordinary methods, by means of shafts and tunnels. With the establishment of hoists and conveying machinery, of especial necessity will be the installation of a ventilating plant, for the dust derived from the gilsonite in mining is exceedingly annoying, penetrating both skin and lungs, and there remaining, except under the action of a solvent, impossible, of course, in the latter case. This peculiarity of the mineral is due to its insolubility in water and to its softening under the temperature of the body. It is therefore very different in behavior from coal dust, which readily succumbs to water, and can in a measure be thrown off by the lungs. From the skin of the miner gilsonite dust is commonly removed by the application of kerosene oil, but any of the solvents given in Table III may be used. Besides the harmful results in breathing it, the dust has proved a dangerous element in mining, being highly explosive when its mixture with atmospheric air acquires a certain ratio and it is then disturbed by the accidental fall of a lighted candle through it. Safety lamps can be used only with difficulty, on account of the heat melting the substance and forming a film over glass or gauze.

Thus far ventilation has not been attempted, the men using aspirators, sponges, or other methods, the dust of the mine being laid once a week by spraying the walls with water, which finds its way to a sump, and is raised in buckets. Any of the methods of ventilation adopted in coal mines, mills, etc., would in great degree remedy the inconvenience and danger attending the winning of the product.

Timber suitable for mining purposes is in most instances from 10 to 30 miles distant, and for fuel but little less. For the mines, however, comparatively little will be required, for the veins are vertical, the strata nearly horizontal, and the sandstones and shales will stand well with the minimum support. For fuel much more timber will be needed, unless coal be employed, transported from points 25 to 75 miles away.

Water is rarely to be found in position advantageous for utilization. From experience at the Culmer mine, it would seem that the mine water can be used neither for domestic nor for steam purposes. White

River will supply mines located in its canyon, and others near by on the flat above, but the latter only by comparatively expensive pumping plants, capable of heavy lifts of 1,000 to 2,000 feet.

Electric power of considerable efficiency may be obtained from White River.

The extraction of gilsonite can best be accomplished with the pick alone, as the material is very brittle and readily yields. It also strips clear of the walls, and no separation or sorting is required after once getting below the superficial zone affected by atmospheric influences. Blasting is not required. One man can mine and sack and send to the surface by horse-whim 2 tons per day of ten hours, the present wage cost being about 87½ cents per ton. The chief items of expense, other than wages, will be fuel, ventilation, pumping, and water supply.

COMMERCIAL CONSIDERATIONS.

TRANSPORTATION ROUTES.

The region within which the uintaite (gilsonite) veins occur is deficient in transportation routes. From the north it is inaccessible except by very indirect roads. To the south it is separated from the valley of the Grand and Price rivers by the rugged Roan or Book Plateau and its canyons, though the travel of to-day is in this direction, the product of the Culmer and Duchesne mines being taken by wagon to Price, on the Rio Grande Western Railway. Up Strawberry Valley and across the Wasatch Range the route is somewhat more difficult than the last, and the distance to railroad is considerably greater. The mines in the edge of Colorado now ship their product by wagon over a circuitous and hilly road via Meeker to Rifle, on the Denver and Rio Grande Railroad, 125 miles. It is thought possible, however, by those familiar with the country, to find a feasible route 50 to 70 miles shorter than this directly southward along the State line. The Bonanza and Cowboy group of veins is a little more remote from Rifle than are the Colorado openings, though perhaps attended with no greater difficulties of transportation. By the way of Fort Duchesne to Price the route from these veins is about 180 miles. The vein of uintaite (gilsonite) on Upper Evacuation Creek is, perhaps, a little more inaccessible than any of the others, unless it should be proved possible to establish a route directly south across the Roan or Book Plateau, when it would become the nearest of all the deposits to railroad communication.

The cost of freighting the product of the Duchesne and Culmer mines to rail is now $12 to $15 per ton. Railway freight to Chicago is said to be about $9 per ton. The total cost of mining and placing the material in Chicago or St. Louis is therefore not far from $25 per ton. Office and management expenses may increase this to $30. The present price per ton in Chicago and St. Louis for the best grade is $40 to $50, leaving a net profit of $10 to $20. The factors in a reduction of the price to the trade will be railroad transportation direct from the Uinta Basin, which seems probable at a future day, and competition, which will arise should any equable distribution of mining claims be made among the numerous companies that will doubtless be inclined to work these great deposits.

USES OF UINTAITE (GILSONITE) IN COMMERCE.

Uintaite (gilsonite) is employed chiefly in the manufacture of black, low-grade brush and dipping varnishes, such, for instance, as are used on the various kinds of iron work and as baking japans. As a high-grade rubbing varnish for coaches, ebonizing, and similar uses, it is said to be unadapted. By one company it is also employed for mixing with an asphaltic limestone in the manufacture of paving material.

Other uses, according to the statement of Mr. E. W. Parker in Mineral Resources of the United States for 1893, are:

For preventing electrolytic action on iron plates of ship bottoms.
For coating barbed-wire fencing, etc.
For coating sea walls of brick or masonry.
For covering paving brick.
For acid-proof lining for chemical tanks.
For roofing pitch.
For insulating electric wires.
For smokestack paint.
For lubricants for heavy machinery.
For preserving iron pipes from corrosion and acids.
For coating poles, posts, and ties.
For toredo-proof pile coating.
For covering wood-block paving.
As a substitute for rubber in the manufacture of cotton garden hose.
As a binder pitch for culm in making brickette and eggette coal.

It is probable, however, that the uses of gilsonite as enumerated in this report of Mr. Parker's are in most instances still in the experimental stage.

Prior to the use of gilsonite in manufactures the raw material is crushed to a half or three-fourth inch size and screened, an operation by which any chance foreign matter is removed. The screened material is usually designated "first grade," the screenings "second grade." The latter are said to be about the quality of the second-grade mine product.

In the manufacture of varnish, gilsonite of the higher grade is heated with linseed oil to a temperature of about 400° F., in a tank built for the purpose and fitted with a device for stirring. After thorough liquefaction and mixing, the resulting product is run into a second receptacle and thinned with either turpentine or naphtha, according to the ultimate product desired, the turpentine being employed in all the better grades, naphtha making an inferior quality and being used only on account of cheapness. After thinning it goes to a receiving or storage tank, from which it is drawn into cans and sealed ready for the trade. This is the general practice, devoid of details, which vary widely according to the quality of varnish desired, the purpose for which it is to be employed, and the personal experience of the manufacturers in their study to produce results the most satisfactory to the consumers. It is an occasional practice to dilute the gilsonite with resin, an operation which, carried too far, renders the varnish product made from it comparatively worthless, and in all cases counteracts in greater or less degree the very properties for which the gilsonite is so valued, namely, elasticity. This property of elasticity is considered one of the most essential qualities of a varnish, and in imparting it gilsonite is said to be unapproached by other asphalts. The writer has seen sheet tin coated with the varnish subjected to the severe test of repeated bending back and forth, followed by hammering the bent edge with a piece of steel, without the slightest detriment to the japanned surface either by cracking or loss of luster. In this respect it shows a marked similarity of result to an enamel made from wurtzilite or elaterite, a mineral preeminent for its elasticity.

The color of varnish made from gilsonite has a brownish tint in thin coats, but this may be largely remedied by a heavier, yet still thin, application. In this connection it is suggested by the writer that it may be possible to employ the nearly related mineral albertite, which, unlike gilsonite, has a jet black powder and streak. But it is not yet established, so far as can be learned from the literature on the subject, whether albertite possesses the same elastic properties as gilsonite. If it does not, the problem is still unsolved, except, of course, by a direct admixture of a foreign matter of decided black color.

By some manufacturers the use of gilsonite in preference to other asphalts is considered advantageous from the standpoint of economy, as it is said to require less linseed oil to obtain equally satisfactory results, to have a greater capacity for the thinning medium with correspondingly less deterioration from its use, and to maintain an equal bulk of product with employment of a smaller percentage than of other asphalts.

The present cost of varnishes of the first quality made from gilsonite is about $1.25 per gallon, and somewhat lower for lower grades. From the evidence gathered by the writer the opening of the gilsonite veins and competition among mining companies would tend to lower the price of the raw material to manufacturers, but many of the latter do not believe an increased supply of this would materially lower the price of the varnish, as competition has already brought this to a limit. There would result, however, an improvement in quality among those who are now inclined to adulterate with resin, and the foreign asphalts used for the same purpose would be driven almost entirely from the markets of the United States. The quantity of gilsonite used by varnish manufacturers would also doubtless be considerably increased, but the total consumption for this purpose would always be comparatively small, for among even the larger concerns a car load often lasts six months.

In the manufacture of paving cement, gilsonite of the second grade is melted with petroleum residue in a tank similar to that used for its liquefaction with linseed oil for use in varnish making. To the heated mixture is added ground asphaltic limestone carrying perhaps an average of 18 to 20 per cent asphalt. After thorough mixing and heating, the material is drawn from the tank into barrels and stored ready for shipment. For paving it is remelted, the requisite amount of sand is added, and the mixture is then spread like the ordinary asphaltic paving material in such wide use in the larger cities.

THE GLACIAL BRICK CLAYS OF RHODE ISLAND AND SOUTHEASTERN MASSACHUSETTS.

BY

N. S. SHALER, J. B. WOODWORTH, and C. F. MARBUT.

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CHAPTER I.

By N. S. Shaler.

ORIGIN AND CHARACTER OF THE CLAYS.

AIM OF THE REPORT.

The aim of the following report is to set forth what has been learned concerning the origin, nature, and distribution of the deposits commonly known as brick clays which occur in eastern Massachusetts and in Rhode Island. The greater part of this knowledge has been derived from field work done by the Atlantic Coast division of the United States Geological Survey, in connection with the preparation of the maps of the surface and under geology of the district so far surveyed in southern Rhode Island, on the islands of Marthas Vineyard and Nantucket, and on Cape Cod. Much of the matter has long been in the state of office record, awaiting an appearance in the folios which are to set forth the surface geology; but as those folios will necessarily present the results in a somewhat scattered form, as the points to be discussed have a close relation to the history of glaciation in the above-mentioned States, and as the matter has a certain economic importance, it has seemed advisable to present the data at this time and in this manner.

Although students of glacial phenomena in North America have, to a certain extent, recognized the occurrence of more than one period of ice action in the time which has elapsed since the beginning of the Pliocene age, the discrimination of the work has not yet attained anything like the completeness to which it has been brought in northern Europe. This tardiness in the advance of the inquiry concerning the development of glacial activity in the Pleistocene period in this country is probably to be explained by the fact that the studies of the work of the great glacier have, in the main, been carried on in regions unfavorable to the preservation of a complete record of the events. In northern Europe, particularly in Great Britain, the neighborhood of the sea, together with the considerable oscillations of the land which occurred during the Glacial period, favored the formation of a record which can readily be interpreted; but in this country, where most of the ice work was done in the interior of the continent, these favorable conditions have been lacking.

It appears probable that, of all parts of this country, the region best placed for the interpretation of the glacial record is that lying between and including northern New Jersey and Cape Cod. There the ice, at the time of its greatest extension, reached and slightly overpassed the present shore; and in the waning stages of the glacier it fell back stage by stage to more northern lines. At the same time, in the opinion of the senior author of this paper, the sea to a greater or less extent covered the lands, thus permitting the formation of the deposits which indicate the steps of the change.

The field covered by these studies extends in general from the Merrimac River to the western border of Rhode Island, but, as will be noted, incidental references are made to localities beyond the area indicated.

The suggestions herein contained concerning the economic value of the clays, though limited in their character, are based upon a considerable amount of information which has been gained only in small part in the progress of this investigation. In a larger share it is the result of many years of private observation in the field and of conference with those who are engaged in working the clays. It will be noted that these suggestions lack the value which could, and indeed should, be given them by a careful laboratory study of the materials; and it is very much to be regretted that there is as yet no clay laboratory in this country wherefrom trustworthy information as to the value of such deposits can be obtained.

ORIGIN AND NATURE OF THE BRICK CLAYS OF THE DISTRICT.

The classification of clays is still the subject of much controversy. A primary division, based on the physical history of the materials, may be made by placing in one group the deposits which have been formed by the decay of feldspathic rocks in place, the materials not having been subjected to transporting action after the disintegration occurred; in a second the deposits containing materials which have been brought to their sites by the action of water since the decay was effected; and in a third group the clays which are found ordinarily beneath beds of coal, but sometimes in other positions. Deposits of the first group depend for their constitution mainly on the chemical nature of the original material, but in part, also, on the constituents of the percolating waters which effected the alteration of the mass from its feldspathic state. The most notable feature of the second group is that the feldspathic matter has been to a considerable extent mixed with materials of other than feldspathic origin. In most cases this admixture is largely of quartz, but in practically all instances a great range of mineral substances is contained in the beds. In many cases a certain amount of secondary decay has occurred after these clays reached their present position. In the third group of deposits the mass was originally in the state of an "underclay"—that is, a soil in which a swamp vegetation found root, and from which the plants had taken all the soluble basic material, such as lime, potash, and soda, the residue, composed mostly of siliceous matter, forming what is known as "fire clay," a substance which has been deprived of the elements that will cause it to flux when much heated. In a strict sense these underclays should not be so called, for they are really not of a clayey nature.

All the clays in the field here considered belong to the second group in the foregoing rough classification. In the Carboniferous district of the Narragansett Basin there are, it is true, certain underclays lying beneath the coals, but these deposits have been so far altered by the metamorphic processes to which the rocks have been subjected that they are no longer suitable for making fire brick. They will therefore not be discussed in this report. Moreover, in some of the decayed granitic rocks of this district there are masses of more or less feldspathic material, so disintegrated by the pre-Glacial and post-Glacial decay that they may be fitted by washing for the manufacture of high-grade pottery clays. Nevertheless, these materials have as yet no economic value, nor are they likely to be worked for a long time to come. The only clays which will be considered in this report, therefore, are those which are products of disintegrative actions, mechanical and chemical, and which owe their present positions to the action of water in relatively recent geological time.

THE CRETACEOUS AND TERTIARY CLAYS OF SOUTHEASTERN MASSACHUSETTS.

In southeastern Massachusetts, principally upon the Island of Marthas Vineyard, there occurs, as is well known, a thick section of beds, mainly of a clayey nature, which are extensively exposed on the cliffs of Gay Head and elsewhere. These deposits, which range in age from middle Cretaceous to upper Tertiary and thence to Pleistocene, have been to some extent described in a report on the geology of Marthas Vineyard.[1] As stated in that report, the Cretaceous and Tertiary deposits on Marthas Vineyard were evidently formed under peculiar conditions. The region whence they came, apparently a granitic area,

[1] Seventh Ann. Rept. U. S. Geol. Survey, 1888, pp. 297–363.

had long been the seat of extensive atmospheric decay. The rocks were then subjected to intense abrasive action, and the débris resulting therefrom was rapidly conveyed to its present site. Owing to variations in the intensity of action of the transporting agent, or, perhaps, to variations in the distance to which the materials were carried beyond the shore line, the beds differ much in character. In part the Cretaceous strata are composed of clay and sand, so mingled with vegetable matter that the deposit has the character of an impure lignite; in part they are of clay, or of clay mingled with more or less sand, the deposits often being so pure that they afford excellent material for the use of the potter. These clays range in color from red to white. Although valuable for certain purposes, they are not well suited for making brick.

Above the level of the Cretaceous and Tertiary beds, as before noted, there comes an extensive series of deposits designated in the above-mentioned report as the Weyquosque beds. These beds, which attain an aggregate thickness on the southern part of the island of not less than 200 feet, were evidently formed after the principal dislocations which affected the lower-lying series had been brought about. They have themselves been somewhat tilted, but their relation to the more folded rocks clearly indicates that only a very small part of the dislocation which has taken place on this island occurred after their formation.

It appears likely that the Weyquosque series, as defined in the above-mentioned paper, is to be divided into two sections, the lower having been the most affected by the dislocating forces, the upper hardly, if at all, exhibiting marks of such work. There is also a certain difference to be noted in the character of the débris contained in these two sets of beds. In the lower-lying this débris is somewhat coarser and more generally sandy. Moreover, the upper section shows traces of nodular concretions, somewhat resembling those occurring in the clays of the estuarine deposits of the Connecticut Valley. This upper part of the section is of a finer nature and exhibits less of this action.

The Tertiary and Cretaceous beds of Marthas Vineyard occupy almost all of the high-lying ground in the western portion of the island. The exceptions are where bands of the infolded earlier Pleistocene sands and gravels occur. In the eastern section, or in that part of it which is covered by the great sand plain which is so conspicuous a feature on that portion of the island, the beds probably exist, though at a low level, one much beneath the present plane of the sea. The evidence goes to show that in this section the deposits were worn down when this portion of the continent stood at a much higher level than it now occupies, the wearing being probably due to the action of streams, the head waters of which, draining eastwardly, are now traceable in their remnants on the highlands of the western portion of the island. Here and there, particularly in the section along the shores of the lagoon near Vineyard Haven, higher points of this Marthas Vineyard series, including a portion of the Tertiary and perhaps the

Cretaceous beds, still exist, at the height of a few feet above the level of the tide.

On the eroded older sections of Marthas Vineyard, as above noted, the Weyquosque series, in another period of subsidence, which carried the surface at least 150 feet below its present level and probably to a much greater depth, was laid down. During the Weyquosque period beds of that age must have covered the larger part of the surface of the island, all, indeed, except a small remnant which lies above the height of 150 feet. Remnants of the deposit occur at the last-mentioned elevation on the southern side and near that height in the northern part of the island. They are also found in small patches beneath the sand plain at Cottage City. The facts indicate that since its deposition, in a period of reelevation which carried the island again above its present height, these beds were much worn away, so that on the northern side of the district they were nearly destroyed and on the western portion much reduced in area and in thickness. The evident reduction in thickness validates the supposition that they once mantled over the larger part of the island. Their preservation in the western district appears to be owing in part to the fact that they filled in the reentrants and valleys and were thereby somewhat protected from destructive action arising from the sea and the atmosphere.

Beds which from appearance and from general stratigraphic relations, so far as these can be determined, seem to be of the same age as the Weyquosque plentifully occur on Nantucket and Cape Cod. On the first-named area they appear to underlie the whole of the island, having there a much greater continuity than on Marthas Vineyard. This is probably due to the fact that their level is prevailingly lower and that, owing to the lack of older topography, they more completely mantled the whole of the area. At some points, particularly near the town of Nantucket, these beds were shown in tilted positions, indicating perhaps orogenic action. As the surface of Nantucket has but little relief, and as no deep borings have been made, the thickness of the series and its character in the lower parts are unknown.

On Cape Cod beds supposed to be of Weyquosque age appear to underlie the great part of the salient. They are not generally exposed in their original state above tide level, but they have been found by the senior contributor to this paper by slight cuttings at various points in the eastern portion of the town of Falmouth. The existence of the beds is most commonly shown by the presence in the drift of large, usually more or less rounded masses, not infrequently containing several hundred cubic feet of the clay which has been disrupted from the formation and conveyed for some distance by glacial action. These masses, for the reason that they were useful in hardening sand roads of the cape, have been more or less sought for by the road masters, and the greater number of those once exposed to view have been dug away. In some cases these so-called "clay pounds" may have been projecting points of the beds which were covered after the glacial erosion by the general envelope of washed gravels, but in most instances—in all that have been seen by the writer—they were distinctly bowlders, if such a term may be applied to soft materials. In a section formerly existing near the Nobska Hotel, at Woods Holl, several of these rounded masses, some of them having a diameter of as much as 5 feet, have been from time to time exhibited, the surfaces being covered with large pebbles which had been driven into the clay during its transit. It is not unlikely that at the time of its disruption from the parent mass these fragments were considerably harder than they are at the present time. This was shown by the fact that where the Weyquosque beds on Marthas Vineyard have been freshly bared by the frequent landslips which occur there the material is so firm that an ordinary pick can not well be driven into it at one stroke to the depth of more than 1 or 2 inches. After exposure to the action of the atmosphere the material becomes relatively very soft.

There is reason to believe that the Weyquosque series originally occupied a very wide field on and off the shore of southeastern Massachusetts. We can not account for the existence of such distinctly stratified clays in the positions which they now occupy without supposing that they are the eroded remnants of an originally far-reaching deposit which extended with great continuity along the shore and probably far beyond the most seaward positions in which they are now found. The erosion which led to the present fragmentary state of the deposits must have been effected, in good part at least, when the region had a much greater elevation than it has at present. This matter will, however, be more fully discussed later in this report.

So far, clays having the character exhibited in the Weyquosque series have not been found to the north of Plymouth Harbor. South of that indentation, in the town of Plymouth, beds apparently belonging to this series are plentifully exposed along the marine bench, the cliffs of the material attaining at points a height of 20 feet or more. On this portion of the shore the indications of orogenic disturbance are slight, the strains which effected the dislocation of the beds on Marthas Vineyard having apparently been much less in this more northern field. The lower-lying clays of the Marthas Vineyard series, those of Tertiary and Cretaceous age, are not known to the north of that island, or to the west of the Elizabeth Islands, where some small exposures show that they are still in their original position. Inasmuch, however, as beds of greensand belonging to the Miocene period exist in Marshfield, Mass., there is a possibility that the older Cretaceous clays may also be discovered in some of the depressions in the older rocks which exist along this shore.

Beyond the limits of the Cretaceous, Tertiary, and earlier Pleistocene clays of the Cape Cod and island districts of Massachusetts the deposits of a clayey nature are clearly to be placed in Glacial time. As will be noted in a subsequent section of this report, it may be claimed that the Weyquosque series also comes between an early ice invasion occurring some time after the close of the Tertiary and before the later advances of what is perhaps to be more properly called the ice epoch.

The clays of the mainland of Massachusetts, excluding the Weyquosque series, as before noted, consist in the main of deposits which occupy the lowlands bordering the shore, extending in tongue-like projections up the valleys of considerable rivers, but not usually attaining the height of more than 50 feet above the level of the sea. In addition to these there are occasional patches of tolerably good brick clays, which lie at a greater height, but these detached, higher-lying masses are generally in positions where we may assume that they were fenced off from the sea, at the time of their deposition, by local barriers, in most cases of glacial drift, but occasionally of remnants of ice undergoing the slow melting which occurred where they were deeply buried beneath drift materials. The facts justify the statement that normally, though with many interruptions, along the whole coast from Nova Scotia southward to the margin of the glacial sheet, where the front of the ice crossed the coast in New Jersey, there exists, or has existed before it was in part scoured away, a tolerably continuous sheet of clay, having a singularly uniform composition, being in this regard unlike any other deposit known along this shore. At many points, particularly in the embayments, such as Boston Harbor, this sheet of clay appears at low tide in the form of extensive mud flats, the upper portions of which are often occupied by layers of oyster and other shells to the depth of some feet. Below this shell-bearing zone, the deposits, so far as observed, are prevailingly inorganic, though the clayey portion of the material is the same as that which is found in the upper, fossil-bearing zone. This fact, which has been observed along the coast from Eastport to Plymouth, leads to the conclusion that while these clay beds began to form in conditions which denied to marine life access to the waters in which they were deposited, the process of deposition possibly continued, at least in certain places, until life obtained a foothold along the shore.

Observing the processes now in action along the coast line, it appears probable that after the formation of tolerably continuous clay deposits, most likely accumulated beneath the sea, the portions of this field nearest the shore line were subjected to a large amount of erosive work, in part accomplished by atmospheric agencies, but in larger part effected by the action of coast waves and currents. The share of the atmosphere in this erosion appears not to have been great, as is indicated by the fact that nowhere do we find extensive deposits of clay lying as continuous sheets and undergoing down-cutting, such as would be manifested by the formation of deep, freshly carved valleys in the beds. As before noted, in southeastern Massachusetts at least, the clay fields lie in the valleys, and, as will hereafter be described, they are usually deeply covered by later accumulations formed during the Glacial period. As we go northward from Massachusetts Bay, the level-topped or terrace-like clays begin to rise above the plane of the sea and form accumulations outside of the valleys. North of the Merrimac, and thence eastward in Maine, with many broad interruptions, these terrace clays are evident, even as a feature in the landscape. There, too, they are almost everywhere covered by layers of sand and gravel, and the valleys carved in them are rarely of recent origin. In part they may be due to interglacial river work, but in a considerable measure they may be ascribed to tidal currents. As the study of these clays in the field north of that we are considering has not as yet been well advanced, further discussion of these deposits is necessarily postponed.

Below the level of high tide, where current and wave erosion is effective, the process of removal of the ancient, probably continuous sheet of clays has been accompanied by a remaking of the detrital matter, or at least of a part of it, in the mud flats which are so commonly found in the zone between high and low water. This action may be observed at any time when the waves are beating against clays which are exposed to their stroke. The water thus muddied is borne by the tide into the reentrants. So long as the current is moving rather swiftly the detritus is held in suspension. In the periods when, between high and low tide, the currents are stilled, the matter drops to the bottom, there to be quickly brought into such coherence with previously formed deposits that it is not likely to be scoured away in the next tidal swing. This action perhaps accounts for the formation of the upper portion of the clay layer, which contains organic remains. It clearly explains the considerable share of clay which is generally found in the accumulations formed by the growth of a vegetation which lives on our tidal marshes.

It is easy to see that the reworking of the original clay sheet or apron which appears at one time to have extended along this coast in tolerably perfect continuity has served somewhat to efface the evidence as to the character of the deposits and their distribution. It has clearly operated to increase the thickness of the deposits in the reentrants and to thin or altogether destroy those parts of the apron which have been subjected to the action of the waves during the oscillations of the shore line which have clearly occurred since the bed was formed. At least two of these swings are determinable, one downward, as is shown by the fact that some of the submerged forests rest upon these clays, and another upward, as is indicated by the fact that clays clearly of marine formation extend above the level of the present shore line.

ORIGIN OF THE MATERIALS CONTAINED IN THE WEYQUOSQUE AND OTHER POST-TERTIARY CLAYS OF THE DISTRICT.

Although no extended microscopic investigation of the clays treated of in this report has been undertaken, the evidence is sufficient to show that they are not of ordinary fluviatile origin. This is indicated by the fact that, with the exceptions noted, they are destitute of organic remains; also by the fact that they are disposed in continuous sheets which have no evident relation to river action. The only other apparent source of these materials is to be found in glacial work, which has evidently been very effective on the rocks that yielded clay to detritus-making actions on this part of the continent.

CONDITIONS OF ABRASION IN GLACIAL ACTION.

It is evident that the conditions of abrasion as they are affected by a glacial sheet, particularly where the work is done on massive rocks, favor the extensive formation of fine-grained materials. In a general way this fact is indicated by the state in which the bosses or roches moutonnées have been left by the ice sheet. They are in most instances particularly smooth and polished. As was noted in the special inquiry on the erosion of Iron Hill in Cumberland, R. I.,[1] the greater part of the surface of granitic and other equally compact rocks is found in a smooth or almost polished state. Occasionally the surface is so uniform that it has a slight mirroring quality. In general the depressions from which large blocks have been removed occupy only a small part of the surface. Frequently less than one-twentieth of the area indicates such work of rude disruption. Even the scratches on the rock are such as would be formed where the greater part of the material taken out was broken away in a state of such fineness that it would form mud rather than sand. The facts go to show that the abrasion done, at least in the closing stages of the ice time, resulted in converting by far the larger part of the detritus into very fine-grained material. Still further, the energy applied to the dragging and shoving of the waste contained in the lower part of the glacier, the shearing action to which it was exposed in the ice, and the tumultuous movement of the subglacial streams, which evidently carried large amounts of detritus, exposed the eroded fragments to additional abrasive action, operating in a manner to produce fine-grained waste.

A study of the facts has convinced the writer that the coarser drift materials—the sand, pebbles, and bowlders which attest the glacial work—constitute but a small portion of the detritus that was formed during the ice epoch. It should also be noted that when the last ice epoch began on the part of the continent under consideration the rocks which underlie it had been subjected to a long-continued process of subaerial decay, which had doubtless softened them to a considerable depth. That such was the fact is shown by the survival of the ancient decay in many portions of New England, at points where it is evident that some score of feet of the superincumbent matter must have been removed by glacial action. This preglacially softened rock, though it

[1] See The conditions of erosion beneath deep glaciers, based upon a study of the bowlder train in Cumberland, R. I., by N. S. Shaler: Bull. Museum of Comparative Zoology, Cambridge, Mass., Vol. XVI, No. 11, 1893. Published by permission of the Director of the U. S. Geological Survey.

probably afforded here and there materials which would pass into the state of bowlders, must, to a very great extent, without much abrasive action, have passed into a condition of very fine division and therefore have been free to go in the subglacial or open rivers to the sea. This view still further reenforces the conclusion that the products of glacial action must have been mainly in the form of finely divided materials, such as form beds of clay.

It may be objected to the views above noted, as to the relative value of the erosion which gave rise to coarse and to fine materials, that the abrasive work of the glacier during the later stages of this action, being of less intensity on account of the diminishing thickness of the sheet, led rather to polishing than to plucking, while the reverse may have been the case when the ice was thicker. In answer to this statement it may be said that the observations of the writer on the Swiss glaciers has led him to the conclusion that the ice, even where its section is of considerable depth, rends few large fragments from the bottom, almost all of the material in the terminal moraine being evidently composed of fragments which were dropped upon the surface of the ice stream. Moreover, where it is possible to penetrate through crevices to the bed rock and observe what is there going on, the projecting masses of the bed are seen to be undergoing scratching and polishing rather than massive disruption. Furthermore, in New England and other glaciated fields of similar character the last advance of the ice led to the formation of many extensive frontal moraines composed of bowlders, which preserve in many cases a very angular form, and which certainly had not been subjected to the considerable decay which they would have encountered if they had been left upon the surface during the long interval between the earlier and later advances, an interval the value of which is to be noted in a later part of this report. Still further, the small amount of clay which is contained in the later-formed deposits of the glacier, particularly of the sand plains, apparently indicates that there was no particular accentuation of the erosive work, leading to the production of fine materials, at this stage in the epoch.

It should be said in qualification of the foregoing remarks that there remains a considerable amount of clay contained in the till deposits. This clay appears, by the chances of transportation, never to have been subject to sufficient water action to enable it to find its way to subglacial streams and thence to the sea. In the portion of New England which lies to the east of the Connecticut River the observations of the writer have led him to believe that the share of the material which has a character such as that in the stratified clays under consideration probably does not exceed 10 per cent of the till mass, and in eastern Massachusetts the proportion may fall as low as 5 or 6 per cent. As the average thickness of the till in the last-named area most likely does not exceed 15 to 20 feet, the total amount of clay remaining in the stratified drift is inconsiderable when compared with the vast amount which must have been produced with such abrasion as has been described as occurring on the bed rock. It may also be noted that here and there in the region east of the Connecticut, and to a greater extent in the Hudson Valley, the till is so rich in clay that it may in places be used for making brick, though the product is generally so rough as to be substantially unsalable in the general market.

It may fairly be presumed that the conditions which led to the transportation of the clay-making materials from the front of the ice toward the sea were as efficient in Glacial time as they now are in the fronts of the Swiss glaciers. In that district, as has been determined by experiments made by the writer, the quantity of fine sediment which in a given period goes forth in subglacial streams in a state of suspension is several times as great as that which is accumulated in the moraines. This suspended material has been laid down in the upper portion of the basin of Lake Geneva in such quantity that one-third of the valley has been brought to or above the level of the lake. It may furthermore be remarked that the clay material from the Swiss glaciers of the upper Rhone would have gone straightway to the sea or to the alluvial plains bordering the lower portions of the river systems on which they lie but for the several catch basins which so generally afford their waters a chance to deposit the suspended materials borne from beneath the ice arches.

The extent to which the finer material derived from glacier wearing may be carried away to the sea, even for great distances, is shown by the prevailing lack of the clay deposits on the front of the ice sheet where it stretched across the northern part of the Ohio Valley. In the most of that district the ice front lay upon a table-land which over the greater part of the surface, in the western part at least, does not have steep inclinations. Nevertheless, while a large share of the coarser drift remains near the margin, the materials which might have formed brick clays have evidently gone forth in the drainage to the sea. It is true that here and there along the Ohio River, perhaps owing to subsidence, which may at one time have carried the ocean level to a point several hundred feet above the Ohio at Cincinnati, there are considerable accumulations of brick clays, but in the Ohio gorge, from its source to its mouth, the amount of these deposits is not great enough to account for more than a very small fraction of the fine detritus which must have been poured forth from the ice front.

PAUCITY OF BRICK CLAYS IN ELEVATED DISTRICTS OF MASSACHUSETTS.

The paucity of brick clays in the more elevated portion of eastern Massachusetts, even where the attitude of the surface seems likely to have favored the formation of such accumulations, is not easily accounted for. Thus in the region around Lake Quinsigamond and Lake Cochituate, where on a priori grounds it might be assumed that extensive clay deposits would occur, they appear to be lacking. An explanation of this fact may perhaps be had in the supposition that in the retreat of the ice these basins were the seat of considerable remnants of the glacier, which became floored over with washed detritus, and were thus long preserved from melting, so that in the time when the clays might have been accumulated there was no cavity in which they could be deposited. It is indeed not improbable that in the progress of the ablation of the New England glacier it may have deserted the highlands, the stagnant masses remaining in the valleys offering over their surfaces a path for the waters coming from the more northern fields, where the sheet remained in activity. It may be remarked that, as there was a considerable depression of the coast line, the belt of country near the sea may have been under conditions which prevented the stagnation of ice remnants, with the consequent effects above described.

DETAILS CONCERNING THE STRUCTURE OF THE CLAYS.

In general the brick clays of eastern Massachusetts and the neighboring districts exhibit tolerably distinct stratification. In the more southern sections, particularly in the Weyquosque series, the alternations of thin layers of sand are less common than in the more northern sections, where a succession of this sort is often distinctly traceable. The cause of these alternations has not been found. It may have been connected with the seasonal variations in the flow of water from the ice front and the consequent carrying power of the streams which did the work. In some sections there is a curious likeness in the thinness of the layers which suggests some such action.

In no case has it been observed that a gradual passage occurs from the typical brick clays to the ordinary sand plains of the New England district, which so frequently, as will be hereafter noted, overlie the clay deposits. There are, however, many sections which show layers of clay interstratified with deposits of which the beds are normally made up of sand or gravel. Such instances are most common in districts beyond the limits of the field under consideration in this report, as, for instance, in the Merrimac Valley. Where these layers of clay occur interbedded in the manner above noted there is not infrequently to be observed a curious accident, a satisfactory explanation of which has yet to be found. The clay bed, especially where it is made up, as is often the case, of numerous thin layers, sometimes as many as eight or ten to the inch, is apt to be thrown into sharp folds, such as might be produced by a compressive strain acting freely throughout the plane of the bed but not in the beds of sand which lie above and below the clay. In a section which the writer observed in the upper part of the Merrimac Valley a layer of clay averaging about 4 inches in thickness and visible for a distance of 50 feet or more was thrown into folds which, if effected by contraction, would have brought about a shortening of its length to the amount of about one-fifth. Above and below was distinctly layered sand, which had not been dislocated but retained its original approximately horizontal attitude. Although this is perhaps the most striking instance which has been observed in this part of the country, like cases where the beds are thicker are not infrequent.

At present there are but two evident hypotheses which may account for this crumpling of the clay layers in the manner above described. The most obvious is that the mass in which they were contained has been thrust by the glacier in such a manner as to produce folding. This supposition seems to be contraindicated by the fact that the layer of clay is the only part of the section which has evidently been subjected to the compressive action. If the sand layers were thus affected they must have taken up the movement either by becoming more solidified or by extending vertically. Considering how improbable it is that a thrust could be passed through a frail mass of sand and clay so as to produce any of the results above observed or supposed, it appears necessary to abandon the supposition that glacial shoving has brought about the wrinkling of thin beds of clay placed as described. The other supposition is believed to be novel and not yet to have been subjected to sufficient criticism to give it much value. It is to the effect that a layer of clay, especially where overlain by a thick series of beds very permeable to water, is liable to certain changes which may considerably increase its bulk. Thus the process of kaolinization and other similar chemical alterations of the various minerals contained in the mass are likely much to increase the mass of the deposit. Furthermore, the downward-penetrating waters, charged since the surface of the country was re-covered by vegetation with a considerable amount of CO_2, are likely to bring various substances into the clay which may be precipitated or combined in the bed in such a manner as to increase its bulk. As the material was originally compact, after the manner of all clays, any considerable increase in bulk would be likely to find expression in the dislocation of the layers, casting them into folds which would have some relation to the thickness of the layers and of the bed as well. In some cases the whole bed might become folded rather than its constituent layers.

The writer has been led to this supposition by observing the effect produced in layers originally limestone and afterward changed into siderite and later into limonite by the action of downward-moving waters bearing iron oxides. Such beds when they attain their limonitic stage exhibit curious foldings, which may affect the lesser stratification or contort the whole bed, and this contortion may take place in a stratum inclosed between others which have not undergone a change.

It is not to be doubted that many cases of contortion of clays in eastern Massachusetts and elsewhere, where the dislocation has taken place along with a like movement of the layers of sand and pebbles exhibited in the section, are due to the thrusting action of advancing ice fronts. The explanations given in the preceding paragraphs are to be applied only to those cases where the contortion of the clay has occurred under conditions which seem to exclude the hypothesis of ice thrust.

PEBBLES AND BOWLDERS OF THE CLAYS.

The pebbles and bowlders which occur in the brick clays of the district under consideration are of importance, as they afford indubitable evidence of the glacial origin of the beds in which they lie. In all the brick-clay deposits which have been observed in the valleys of Massachusetts above tide level, such erratics are found with their surfaces scratched in the characteristic way which is accomplished only by glacial action. In the brick clays of the Boston Basin these erratics are tolerably numerous and frequently of considerable size, often attaining a weight of several hundred pounds. In some cases they are so numerous as to trouble the brickmakers, and at times they are of such frequent occurrence and so far inseparable from the mass that they enter into the brick, to the damage of its qualities, for the reason that while the clay contracts in burning the pebble does not, with the result that a fracture of the mass occurs.

The writer has noted that the included glacial pebbles are more common in the northern and interior portions of the field and less so in the southern part of it. They are relatively rare in the pits at Taunton and at Middleboro. They seem, moreover, to be quite wanting in the Weyquosque sections, except, it may be, in the upper part. It is impossible to account for the presence in these clays, which evidently were deposited in rather still water, of such pebbles and bowlders as have been described without bringing in the supposition of ice rafting. We have, indeed, to suppose that from time to time fragments of the glacier floated over the surface on which these beds were laid down, dropping the pebbles from their mass as the process of melting went on. So far as has been observed, all the pebbles contained in the clays are quite without trace of atmospheric action. They are altogether different in appearance from the fragments which are now being borne away seaward by ice rafts from the shore, and which are at present building into such clay deposits as are forming off this coast. So far as it goes, the absence of any atmospherically decayed pebbles seems to indicate that the glacier at the time when these clays were formed was cutting rocks which were below the zone of previous atmospheric work, and that there were no shores near by on which pebbles were exposed to aerial decay, such as in a few years changes the superficial character of almost all rocks.

As yet the brick clays of this neighborhood have shown very little indication of any of those accidents which prevailingly occur on the bottoms of shallow water. Even where the layers are sufficiently sandy to have readily taken ripple marks if the opportunity had been afforded them, no sign of that feature has been observed. So, too, the evidence of current action of any kind appears very generally wanting. The obvious deduction from these negative facts is that the water in which these beds were deposited was not shallow. The safest inference appears to be that it had a depth of several hundred feet, or, in a word, enough to extinguish the strength of tidal currents or other movements which tend to impress themselves on shallow-water deposits.

GASES DISCHARGED FROM CLAY BEDS.

Mr. Woodworth, in his account of the clays in Rhode Island, states that he has observed there and elsewhere phenomena which seem to indicate the escape of a certain amount of gas which led to the formation of small mud springs. This action indicates that certain of these deposits are undergoing changes which lead to the production of gases. In most if not all cases these alterations are probably due to the decomposition of pyrite, which was imported into the deposits with the unoxidized materials from beneath the glaciers. The same action is observable in the delta of the upper Rhone, in the Lake of Geneva, which, as above noted, is the product of accumulated glacier waste.

In other clay deposits the extruded gases, coming forth, as above described, in peculiar vents, are the results of decomposition of organic materials. Thus in the tidal-flat clays, made up, as before noted, mainly of the more ancient clay deposits that exist along our shores and that are undergoing erosion by marine action, the gases are the product of the decay of vegetable and animal matter, which escape in vertical tunnels, forming, at the point where they enter the atmosphere, pit-like cavities, which at the time of their making are often surrounded by a low, rim-like ridge. In yet other instances, where, as is not infrequently the case along the New England shore, the clays, probably in all cases tidal recompositions effected when the seashore lay at a higher level, overlie forest beds or ancient morasses, gas eruptions occasionally occur which break through the clay layer and give rise to rather vigorous explosions. Thus in the earthquake of 1727 the marshes about Newbury, Mass., were extensively disrupted by violent gas explosions, which appear to have broken through the tidal clays, giving a vent to imprisoned gases formed in a lower organic layer. A phenomenon of the same general nature, though of artificial antecedents, occurred a few years ago at Crescent Beach, in East Boston. A boring made to obtain water passed through the clays which lie at about tide level and entered the zone of the buried forest which is exposed below low-tide level in Lynn Bay. From this level came a considerable discharge of marsh gas, which was fired and burned for weeks with a tall flame, and was extinguished only when, the curiosity of the people being satisfied, the tube was artificially stopped. Although the amount of this gas can not be very large, it is an interesting question whether at several points on the shore it might not have a limited economic value.

THICKNESS OF CLAYS.

Although the means by which we may become informed as to the thickness of the clay deposits in Massachusetts are limited, enough is known to make it probable that the deeper indents, the fiord-like depressions of the coast line at many places, hold thick deposits of this nature. Thus in the case of Boston Harbor, the excavations made in building the submarine tunnel which carries the sewage from the mainland to Moon Island show these clays to have a thickness of 100 feet or more. In other instances, where the slope of the bed rock toward the center of the basin can be ascertained, we find a pitch such as indicates a great depth in the central portions of the depression. On these bed rocks we note the existence of the clays. We can trace them below low water, and soundings indicate that they everywhere occupy the present sea bottom within the inlet. These facts point to the conclusion that the deposits are in their interior parts thicker than we would be led to suppose from studying their landward faces.

BOWLDERS AND GRAVELS AT BASE OF CLAY DEPOSITS.

Wherever access has been had to the bottom of the brick clays at points where the deposits were thick, the existence of a lower layer of pebbly or bowldery material has usually been proved. There is thus reason to believe that these clays rest upon the deposits formed in an earlier advance of the ice. This point is brought out more clearly in the portion of this report by Mr. Woodworth, which deals with the detail of the deposits. Evidence which will be discussed in another part of this report makes it probable that some of the brick clays of this district have suffered as much from erosion by the later advances of the ice as the deposits off the shore have from the action of the sea. It is therefore likely that, thin as are some of the sections which have been obtained, the deposit had in the beginning a vertical and horizontal extent very much greater than is shown at the present time.

COMPARISON OF GLACIAL BRICK CLAYS WITH MORE ANCIENT DEPOSITS.

It seems worth while to note the fact that the character of the brick-clay deposits under discussion, as well as the nature of the associated deposits, may throw some light upon the origin of strata in the lower portions of the great geological section. At various points in that section, from the Lower Cambrian upward, we find thick series of clay beds more or less intimately associated with conglomerates, which indicate intense erosive action. The evidence afforded in the field we are now considering shows very clearly that this character and grouping of beds may naturally result from glacial action. It is therefore not unreasonable to suppose that in the earlier-made deposits the same agent may have had a like share in the formation of such associated beds.

Where, after a long-continued subaerial decay of crystalline rocks, during a time when the processes of decomposition were going on more rapidly than those of erosion could remove the materials, a period of active erosion set in, the beds re-formed from the waste thus brought into the sea or into lakes are naturally composed of much finer materials than those contained in the clays under discussion, while the coarser deposits, those answering to the pebbly beds such as we have in the series we are considering, appear in the form of arkoses. Thus in the strata exhibited at Gay Head, on Marthas Vineyard, where a thick series of deposits has evidently been rapidly accumulated, the evidence goes to show that the waste was taken from a region of decayed granitic rocks. Because of the general absence of pebbles, there is no evidence of glacial work until in the progress up through the section we arrive at a horizon which is probably to be reckoned as Pleistocene. It may be that the clays and arkoses of Gay Head and the neighboring portions of Marthas Vineyard were also due to glacial erosion. It is, indeed, difficult to account for their formation without recourse to this agency, but the proof of such work is much less clear than it is in the case of the recent clays.

OFFSHORE SUCCESSION OF DETRITAL MATERIALS IN A PERIOD OF INTENSE EROSION.

It is necessary to suppose that the deposits formed along a shore line in a period of active erosion, such as exists where the glacial sheet extends to near the coast, are distributed in a somewhat banded manner, the finer waste being laid down the farthest out to sea, the sands prevailingly nearer shore, and the coarser detritus adjacent to the place where it escapes from glacial carriage or torrent action. The occurrence of a thick sheet of clay along the coast of New England, here and there overlapping the land to a distance of a few score miles from the present sea line, indicates that when the clays were laid down the ice front must have been at some distance back from the present shore line. The position of this ice front would perhaps be determinable but for the fact that marine action and the work of later ice advances have to a great extent worn away the shoreward portions of the deposit, as it has also the bands of coarser materials which must have been formed nearer the ice front.

Although so far it has been assumed that the brick clays of southeastern New England are of one age, it must be confessed that the facts in hand are also reconcilable with the supposition that there were several clay-making periods, each marking a retreat of the ice, followed by a readvance. It seems pretty certain that after the laying down of the Weyquosque series there came into the sea an invasion of sand and gravels which are to be discriminated from those formed during the later stages of glaciation. These sands are extensively developed on the Island of Naushon, where they have a somewhat decayed aspect and a prevailing orange color, which indicate long exposure to change-bringing actions. In a well bored on Long Island, in Boston Harbor, of which no good section was preserved, the evidence goes to show that similar sands, having a thickness of 100 feet or more, lie beneath the later glacial deposits which constitute the over-water portion of that island. These sands lie upon clay beds which may be of Weyquosque age or may belong to some stage between the last-mentioned and the newer clays.

CHAPTER II.

By J. B. Woodworth.

GEOLOGY AND GEOGRAPHY OF THE CLAYS.

CORRELATION OF PLEISTOCENE DEPOSITS WITH REFERENCE TO THE GLACIAL CLAYS.

If we define the Pleistocene period in this area so as to include all the time from the first evidence of such action as brought about the distribution of erratics in the last Glacial epoch to the present epoch, this division of geological time finds in the country east of the Hudson River its most complete record in the deposits of the New England Islands. On Marthas Vineyard, as exhibited in the chronological table at the end of this chapter, evidence of early-traveled blocks of granite and other decomposable rocks derived from the mainland on the north is found at a level separated from the last glacial drift of the terminal moraine by a series of deposits and erosion intervals demanding for their occurrence a lapse of time much longer than that indicated by the commonly observed members of the New England drift. In the table the section on Marthas Vineyard is taken as the standard of reference, and the less complete exposures of beds on the mainland are assembled according to the present information concerning them.

UPPER LIMIT OF THE TERTIARY ON MARTHAS VINEYARD.

The occurrence of Pliocene deposits in the Gay Head section was made known in 1895 through the identification by Dall of fossils contained in a small remnant of sands overlying the Miocene beds in the Gay Head Cliffs. Owing to the conditions of erosion at the point on the cliffs where this deposit was observed in 1889, its relations to the overlying Pleistocene deposits could not be ascertained. The Pliocene sands resemble, however, near-by deposits underlying clearly a bowlder bed, which, for reasons to be set forth on the following pages, is regarded as of Pleistocene age. It should be noted before passing to the synopsis of the deposits of this age that the Weyquosque series described by Shaler in 1888 comprises the Sankaty and Tisbury beds of the present report.

FIRST GLACIAL EPOCH.

Overlying the Neocene deposits in the Gay Head section on the island of Marthas Vineyard, as described in the preceding paragraph, is a remarkable bed, the continuity of which is often broken. This layer is at the base of a section of compound gravels and sands not unlike glacial gravels and sands which have been worked over by waves. The constituents of this basal bowlder bed are very largely fragments of the rocks of the mainland north of the locality where they are found. Among other rocks, there has been found a small bowlder of peridotite identical with the rock at Iron Mine Hill, in Cumberland, R. I., fragments of which journeyed to Gay Head in the drift of the last Glacial epoch. This latter circumstance, together with the like derivation and the great size of some of the bowlders, one of them weighing upward of 4 tons, points to the possible glacial origin of the series of earliest Pleistocene deposits in this section. In addition to these erratics the bed contains fragments of the underlying Miocene and Cretaceous sediments, showing the local derivation of some of the material during a time of erosion in which the Miocene along narrow paths was swept away. This unconformity at the base of the Pleistocene is particularly noticeable where the basal conglomerate cemented by iron oxide rests upon the surface of white Cretaceous sands.

Glacial striæ have in no case been observed on the fragments derived from the mainland. On the contrary, the bowlders as well as the gravels and sands overlying the bowlder bed have the appearance of somewhat waterworn materials. The distribution of these deposits indicates that after the transportation of the bowlders they were waterworn in or near their present sites, so that the time of their original journey and first deposition antedates the age of the deposit in which they now occur. The eroding agent was of a nature to attack and remove fragments of the lower-lying strata, as well as to move those of distant hard rocks, for fragments of the Cretaceous and Tertiary beds were accumulated in the bowlder patches preserved in this formation.

The clays of this series are as yet unidentified, nor are there known any of those redeposited residual materials which must have been eroded from the rocks of New England on the advent of a glacial sheet following the long antecedent periods of atmospheric decay.

THE SANKATY BEDS.

The Pleistocene fauna at Sankaty Head, on Nantucket, is found in a series of sands and minor clayey layers involved in the disturbance which is traceable throughout the length of the New England Islands. A similar fauna occurs on Gardners Island under like disturbed conditions. Similar sands, without fossils, however, occur on Marthas Vineyard and Block Island, which are also involved in folds that are shown by sections to have formed the highest beds in the series at the time of the Gay Head dislocation. On account of the well-known locality on Nantucket, the name Sankaty beds is proposed for this series of marine sands, now lying as high as 140 feet above sea level at Gay Head, and 200 feet at other points on Marthas Vineyard. This height, however, as pointed out by Upham for Nantucket, does not indicate elevation of the continent or necessarily any change of the relative level of sea and land, but is due to the folding of the beds.

The occurrence of gravels and sands and some clays in the Sankaty beds along the southern shore of New England, with a fauna indicating waters as warm as or even warmer than those now found south of Cape Cod, is indicative of a difference in age between these formations and the glacial brick clays. The fauna, fragments of which occur in the till of the drumlins in Boston Harbor, probably represents the Sankaty epoch in that part of the shore. So far as our knowledge of the deposits of this time goes, the materials laid down were mainly sands. The clays of the time must have been deposited beyond the now visible portions of the bottom.

GAY HEAD INTERVAL.

The upturning of the soft Cretaceous, Miocene, and earlier Pleistocene strata in the New England Islands affords, by the unconformity of dip between these beds and the newer Pleistocene deposits, a clearly marked plane of reference in the physical history of these islands. This feature, however, does not exist in the region to the northward, where no upturning took place.

On the hypothesis that the overturning was accomplished by glacial thrust, the folding should be contemporaneous with a series of glacial deposits extending northward over the mainland. Evidence of this criterion is lacking, so far as observation goes, in the three eastern islands of this group.

The succeeding deposits on Marthas Vineyard rest upon the broken and eroded edges of the Sankaty and older beds. The precise nature of this unconformity is not clearly exhibited. The overlying beds of the Tisbury series appear to be new importations of detritus from the mainland rather than waste worn from the underlying folded sections of these islands. It is therefore probable that the topography of this unconformity is largely constructional. On Block Island, at Clay Head, it is, however, clearly due to erosion of folded beds.

THE TISBURY BEDS.

Horizontal deposits of rather ferruginous stratified clays and clayey sands form a well-defined terrace along the northern coast of Marthas Vineyard, being recognizable as far west as Gay Head. Everywhere they exhibit a deeply eroded upper surface, confluent with that carved in the older beds of the island. Their marked horizontality is strongly contrasted with the dislocated attitude of the beds in the outcrops of the older folded series which appear at intervals along the shore. The beds are particularly well exhibited in Chilmark and West Tisbury.

At Gay Head, near the wharf, these deposits are locally very bowldery and till-like. Bowlders are also frequently found in the exposures along the West Tisbury shore. The relation of the bowlders to the stratified clays is such as to suggest floating ice as the transporting agent. The probability that these beds were laid down during a time of glaciation, most likely during the advance of the ice sheet, is strengthened by the fact that the beds show little waste from the higher-lying pre-Pleistocene variegated clays and sands at higher levels on the south of them. The distribution of the series along the northern side of Marthas Vineyard is like that which would arise in the case of a frontal moraine terrace, but the occurrence of similar beds on the Elizabeth Islands and in the district of Cape Cod does not support this view of their origin.

The Mohegan Bluff beds on Block Island occupy the same geological position with reference to the upturned beds of the underlying older series and to the overlying drift. The Block Island extension of this deposit is more clearly of glacial origin. In the Mohegan Bluffs the series consists of blue clays, with ice-scratched bowlders above, underlain by sands and gravels, to which succeed clayey beds resting on bluish carbonaceous clays, probably of Cretaceous age.

The significant features which distinguish the deposits of this epoch from the immediately preceding beds in the New England Islands are the occurrence of clays, locally laminated and locally charged with glacial stones and bowlders, and the derivation of the materials from the north.

THE CLAYS NEAR NEW HAVEN, CONN.

The clays in the lower portion of the Triassic valley in Connecticut are earlier at least than one advance of the ice sheet, that which last covered the southern shore of New England. At Berlin, Conn., the stratified clays have an uneven, eroded upper surface, on which rest kame gravels deposited during the presence of the ice; there are also eskers, which appear to lie on the surface of the brick clays, although no sections have been seen showing the clays passing beneath these ridges. Near New Haven the clays were exposed in 1896 on the west bank of West River, showing, as pointed out by Prof. H. S. Williams, a sloping, evidently eroded surface, on which were strewn glacial bowlders and stones, over which were cross-bedded sands contemporaneous with the New Haven sand plain. While these indications show the advance of the last ice sheet over the clays, the facts do not determine whether the clays were laid down in front of the advancing ice of the last epoch or whether they were thus deposited during an earlier advance. The general evidence from southern New England favors the view that these clays are to be regarded as contemporaneous with the Tisbury beds of the New England Islands.

VALLEY EXPOSURES OF THE OLDER BRICK CLAYS.

The occurrence of glacial brick clays in the valleys of southeastern New England, with a mere coating of later drift and over large areas, often without any covering, at first sight appears to militate against the hypothesis of the inferior position of such clays as those which occur in the Boston Basin. The reason for the thinness or absence of the drift overlying the older deposits is found in the circumstances attending the deposition of the sand and gravel deposits during the retreat of the last ice sheet. The ice being thickest in the valleys, it was there the last to melt away. From this arose the deposition of moraine terraces and sand plains about the sides or in the lower courses of valleys, on ground from which the ice had already retreated, while the ice yet in the valley was an effective barrier to the deposition of sands and gravels except in channels and tunnels in the ice. Only when the ice had melted out of a valley and the ice front lay farther north was it possible for more sands and gravels to be washed by extra-glacial streams into the low places which had before for a time been held free from débris. Except where the ice remnants were heavily charged

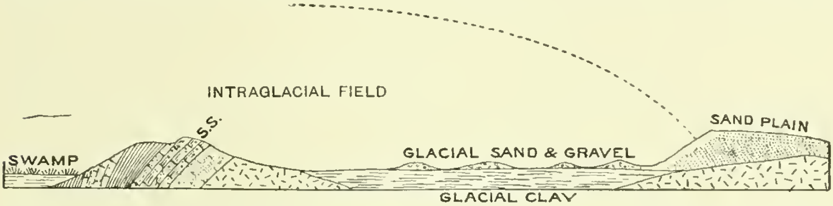


FIG. 34.—Cross-section of a valley and last glacial drift, with older glacial clays and pre-Pleistocene terranes, having a variable thickness of drift, owing to the stand of the ice sheet during its period of melting.

with englacial drift, and rested upon much subglacial drift in transit at the time of stagnation of the ice, the eroded surface of older beds, whether brick clays or the bed rock, appear at or near the surface over broad areas in the valley bottoms. The conditions, repeated with varying details in many clogged valleys in southeastern Massachusetts, are essentially the same as those indicated in the accompanying cross section.

THE VINEYARD INTERVAL.

These deposits, both on Marthas Vineyard and on Block Island, are clearly separated from the last glacial drift of the moraine by an unconformity, the sculpture of which points to ordinary stream action as its cause. The facts are best shown on the island of Marthas Vineyard, the evidence from which field has already been described by Shaler. The bearing of this interval of erosion by open-air streams upon the glacial history of the region is as follows: An interglacial epoch in this district would last longer than in points to the northward; the stream erosion would therefore diminish northward. As far northward as opportunity permitted the action of running water, however, we should expect to find evidence of this unconformity with the overlying last glacial deposits. In the final advance of the ice some erosion would be accomplished, so that in the northern field of the mainland it is necessary to discriminate the effects of the possible earlier stream erosion from the probable later erosive work of the ice. At Boston, as will be described in the chapter on the brick clays of that basin, little more is possible than to point out an unconformable relation of the drift to clays occupying this position.

LAST GLACIAL EPOCH.

Under this head is comprehended all those deposits of glacial origin which can be shown to have been laid down during the advance and retreat of the ice sheet which produced the outermost moraine on the New England Islands. The retreatal deposits of this epoch almost everywhere mantle the surface of New England. Only in exceptional localities are earlier deposits shown at the surface.

The deposits laid down during the advance of this ice sheet within the area of the mainland offer usually no decisive criteria by which they may be discriminated from earlier deposits of like origin. Clay deposits of an earlier advance should exhibit at their base signs of glaciation either in striated rock surfaces or in ice-laid materials. Some indications of this kind have been observed in the case of the clays in the Boston Basin, where they thin out against the rising floor of the rock valleys in which they rest. The principal evidence of succession of deposits is afforded by the section already given as found on the island of Marthas Vineyard. In the following account of the brick clays, therefore, deposits are referred to the last or to the earlier Glacial epochs on the basis of the evidence found at the several localities.

As this evidence is often of a debatable nature, where doubts exist it has been assumed that the deposits belong to the last advance, although further exploitation of the clays may show them to be of much earlier date.

CLAYS OF THE THIRD OR LAST GLACIAL EPOCH.

The deposits of this epoch of glaciation have the widest distribution in the area here described, for the reason that in this advance of the ice and its resurgences earlier deposits either disappeared by erosion or were covered up when the ice sheet melted. The few exceptions to this statement are dwelt upon at length in other sections of this paper. The sand plains, eskers, and kames—in fact, all the important sources of finely divided rock material for masons' and builders' use in this thickly populated coastal region—are derived from the glacial materials laid on the surface in this epoch. The brick clays contemporaneous with these sands and gravels exist in the form of local accumulations, having usually very limited natural exposures; therefore, they are very seldom seen in their entirety. In most cases they lie in the low ground between successive lines of retreatal sand plains and morainal deposits, and are concealed beneath the southern borders of these deposits. To a much greater extent they are hidden by growths of peat and of swamp vegetation. In the cases where the sand plains have been built out over the clays of the bottom the sand plain is commonly too thick to permit of the economic working of the clays thus buried. In the case of the peats and swamps, however, except along the coast at or near tide level, drainage will generally permit the free working of the underlying clays.

PREVALENCE OF SAND IN THE DEPOSITS OF THE LAST ICE ADVANCE.

The most striking feature of the uppermost superficial deposits of glacial origin in this district is their arenaceous character. The deposits, including the till, are sandy rather than clayey. This is so strongly marked, particularly in the morainal belts, that the till is more properly denominated bowlder sand than bowlder clay. In large part this sandiness is due to the nature of the rocks from which the glacial deposits are derived. Granites, granitites, and the conglomeratic sediments of the Carboniferous areas, themselves eroded from the same or similar acid igneous rocks and older quartzites, predetermined in a measure the character of the glacial drift. Their effect is particularly pronounced in the later drift, when the ice sheet derived its débris largely from ledges whose residual clayey waste had earlier disappeared.

The prevalence of superficial sand deposits is, however, partly due to the concealment of the fine clayey deposits made contemporaneously with them by the outgrowth of the sand deltas over the clay. Notwithstanding this burial of clay deposits, there appears to be a smaller amount of clay connected with the last Glacial epoch than is found in the deposits in the same region the stratigraphic position of which indicates an earlier origin. This deficiency is probably due to the fact that the superficial drift deposits are generally the débris left by the retreating, less actively eroding ice sheet. With slackened motion, and therefore decreased grinding of detritus in the ice, less rock flour for making clay deposits would be carried out of the ice by streams. That clays were not in many cases carried out of the ice by streams building sand plains is indicated by the fact that the deposits of sand previously made and lying in front of the growing deltas and beneath the same water level received practically no clay upon their surfaces.

It was rather during the advance of the ice than in the time of its retreat, when it was more or less stagnant and not forming rock flour, that clays were most abundantly deposited. Owing to the farther advance of the ice these accumulations would be subject to erosion. The contemporaneous sand deltas, being uppermost, would be first swept away. It is for this reason, and those above given, that the earlier drift of the area from Boston southward appears more clayey and the later more sandy.

GEOGRAPHICAL DISTRIBUTION OF THE BRICK CLAYS.

THE GLACIAL CLAYS OF THE NEW ENGLAND ISLANDS.

Clays of glacial origin occur in all of the New England Islands, but not in that development which makes the brick clays of the mainland of commercial importance. On Marthas Vineyard and Long Island, at least, the pre-Pleistocene clays of Tertiary and more largely of Cretaceous age far outweigh in importance the Glacial clays.

NANTUCKET.

The age of the clays which appear at the surface on this island has not been definitely determined. An exposure of bluish, rather thin-bedded clay in the western part of the town of Nantucket is folded into high angles and covered by morainal débris. It is probably to be regarded as a member of the Tertiary or Cretaceous series, better known on Marthas Vineyard. Similar clays appear on the eastern shore of the island in a like disturbed condition.

Beneath the kame moraine which forms the northern belt of glacial hills running the length of the island are stratified clayey beds evidently of glacial origin. They have not been explored by means of pits, so that their extent and qualities for brickmaking are not yet fully known. They exhibit the features which are characteristic of the Tisbury beds.

MARTHAS VINEYARD.

The clays which are at present mined on this island for industrial uses are taken entirely from the Cretaceous strata. The glacial deposits of the island, both those of the till and those of the stratified series, are preeminently sandy and gravelly, but the middle member of the Pleistocene series is essentially clayey, presenting several characteristics in common with the older brick clays of the mainland, as, for instance, those of the Boston Basin.

The older Pleistocene, including the bowlder and gravel beds involved in the folds at Gay Head and along the Nashaquitsa Cliffs, and believed to be of the age of the Sankaty fauna on Nantucket, exhibits clays only in the form of thin layers redeposited from the Cretaceous and Tertiary beds.

The middle Pleistocene above referred to is largely developed in Tisbury and Chilmark, on the northern shore of the island. On portions of this shore the formation is almost entirely of sand and gravel. These beds are often ferruginous, and are frequently much jointed in the clayey phases. Valleys from 10 to 100 feet in depth were excavated in this series before the last glacial moraine was laid down upon the area. The sections exposed in these valleys exhibit the occasional presence of large bowlders comparable to those found in the brick clays of the mainland.

The newer Pleistocene of the island includes the broad, stratified sand plain, in which clays, if they exist, are too deeply buried to be available.

BLOCK ISLAND.

Block Island repeats in its topography and geological structure the principal features exhibited in Marthas Vineyard. The area of pre-Pleistocene deposits exposed is relatively very small. Lignites and pyritiferous clays, presumably of Cretaceous age, appear on the east side of the island. At Clay Head white sandy clays are thrown into close folds, in the synclinal axes of which are caught, as at Gay Head, the earliest Pleistocene gravels, the Miocene being wanting. Dark-blue clays, probably members of the nonmarine lignitic Cretaceous series, also appear in the headland at this point.

Subsequent to the folding and denudation referable to the Gay Head interval there was laid down on this area a series of clays, sands, and bowldery clays, best exhibited in the Mohegan Bluffs, on the south side of the island. Portions of these clays are fit for brickmaking, but they are not in a proper position or in suitable beds to warrant exportation. In its relations to the unconformity at Clay Head and to the

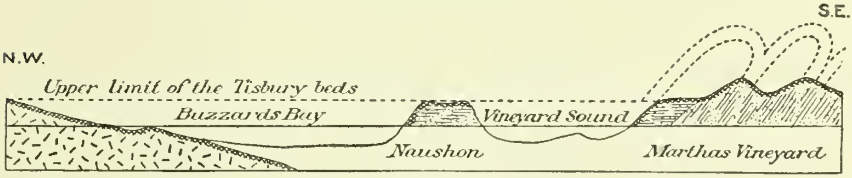


FIG. 35.—Cross-section of Buzzards Bay and Vineyard Sound, showing the position of the Tisbury beds.

overlying morainal drift the Mohegan Bluff series corresponds to the Tisbury beds of Marthas Vineyard. Both series are of glacial origin.

ELIZABETH OR GOSNOLD ISLANDS.

The morainal débris which forms the superficial drift of this group of islands belongs to a stage of the retreat of the ice sheet later than that marked by the moraines of Nantucket and Marthas Vineyard. Beneath the till of the Elizabeth Islands there is a series of stratified deposits agreeing in structure and in general characters with the Tisbury beds, on the south side of Vineyard Sound. Unless the beds on Marthas Vineyard were formed as a morainal terrace, which seems unproved by any evidence now at hand, there is reason for believing that the sound and Buzzards Bay have been excavated in this series. The widespread development of the same series beneath the morainal and stratified drift of Cape Cod confirms this view so far as it demands the former greater extension of the series. The accompanying cross section of the region between New Bedford and Marthas Vineyard sets forth the evidence derived from this field.

The deposits underlying the moraine, according to Mr. C. W. Coman, lately of the U. S. Geological Survey, are well exhibited on Nashawena Island. They are mainly sands and sandy clays. At two localities of limited exposure on the south shore of Nashawena Mr. Coman observed sticky blue clay, similar to that of the "clay pounds" on Cape Cod. At one of these localities the clay contained a few small pebbles and cylindrical casts from one-fourth to 1¼ inches in diameter. Nowhere else on any of these islands was a clay formation observed.

CAPE COD AND THE SHORES OF CAPE COD BAY.

The "Province lands," at the northern extremity of Cape Cod, are composed entirely of drifting sand and beach gravels. The surface of the cape from Truro southward is covered with a coating of bowldery till, or with gravels and sands, the whole the product of the last glacial invasion. Clays are wanting in this series of deposits, except for the rock flour which enters into the more clayey portions of the till.

Beneath the morainal débris of Cape Cod are stratified deposits of sand, clayey sand, and clay. These beds are typically exposed at Highland Light, in Truro. The upper part of the section is here composed of horizontally stratified sands, forming, where steep, smooth, ungullied bluffs; the lower part of the cliffs is formed of clays which are gullied in the manner shown in Pl. LXI.

These beds have all the characters which are necessary to ally them with the sandy clays in the Elizabeth Islands and on the north shore of Marthas Vineyard. They are overlain by till in Truro, but the unconformity which is thus indicated is, as to origin, not accurately determinable. The detailed study of the cape now in progress will probably serve to discriminate between an upper and a lower series beneath the moraines and overwash plains.

Southward, in the arm of the cape, clays are met with along the north shore, cropping out beneath the thinned margin of the terminal moraine. They are well exposed in West Barnstable, in the workings of the West Barnstable Brick Company. At this point the clays vary much in character. Dense blue clay, at one time locally used for making pottery, gives place a few yards off, on the same level, to light-colored clays, with bleached quartz sand admixed in a way to give the clays the appearance of having been made over in part from the Cretaceous and Tertiary deposits which occur along the southern coast of Massachusetts. The upper surface of these clays is manifestly eroded and overlain by deposits of till and stratified sands of glacial origin. Differences of level of as much as 10 feet are to be observed in the above-named workings. The depressions thus indicated are filled in with the stratified drift mentioned above. Bowlders of glacial origin occur in the upper part of the clays and are conspicuous upon the surface of the clay formation in the adjoining fields. The till of the moraine, largely sandy, contains a noticeable proportion of clay, as does also the material of the

SEAL CLIFFS AT HIGHLAND LIGHT, TRURO, CAPE COD.

overwash plain on the south side of the morainal wall. The clay is so large an element in these stratified deposits adjacent to the moraine that the surface cracks in dry weather in a manner unknown on the sand plains westward of Cape Cod Bay. This excess of clay in deposits which elsewhere are typically sandy is apparently to be explained by the action of the ice sheet in eroding in its last advance the clay formation in the Cape Cod Bay area.

The so-called "clay pounds" which are met with in the area of the sand plains on the south of the moraine are interpreted by the senior author as projecting or disrupted portions of the underlying clays, better exposed on the northern side of the moraine at its base.

From the region near the head of Buzzards Bay and northward along the western shore of Cape Cod Bay, through Plymouth into Duxbury and Marshfield, coarse glacial detritus abounds in the form of an interlobate moraine, laid down in part along the margin of the Cape Cod Bay lobe of the glacier and in part along the margin of the lobe which occupied Buzzards Bay. In this intermediate ground the interaction of ice and water interfered with the orderly deposition of clays in the manner in which they are spread out along the front of the same lobes. As a consequence of this embarrassed drainage, the usually sandy till has a larger percentage of clay than is commonly found in southern New England. Added to this cause is also the probable increase of clay in the drift from the erosion of preexisting clays off the present coast line, a source of clay in the moraine which extends through Barnstable.

Brickyards have been opened in the more argillaceous sections of these morainal deposits near Spooners Pond, where, according to Mr. C. P. Sinnott, lately of the U. S. Geological Survey, the clays contain rounded pebbles, and where layers of sand are locally equally conspicuous. On the east side of Beaver Dam Pond is an occurrence of till, called "clay" by the farmers, and said to be 20 feet thick, resting on sand.

Dark-colored, finely stratified clay crops out at Indian Hill, on the shore of the bay, where it is overlain by stratified sands and gravels. Its age is not definitely known.

THE MIDDLEBORO CLAYS.

About 1½ miles northeast from Middleboro, Mass., brick clays occur and were worked in 1895. The clays are interlaminated with sandy layers, the grains of which are mostly of quartz, similar in character and lightness of structure to the sand layer which forms the "topping" of the section. There is a gradual transition in the uppermost clay layer to this top sand. A tolerably well-defined moraine is traceable on the eastern side of the town. These clays are clearly the outwash from the ice sheet at the time this moraine was deposited. The clays are therefore among the newer deposits in the district. An examination of the region shows that the Middleboro moraine is nearly contemporaneous, if the alignment of the deposits be assumed to indicate the identity, with the brick clays at Barrington, R. I., soon to be mentioned. The production of clay at two points in this stage suggests that other deposits will be found along the same line, extending from northeast to southwest through the towns of Plympton, Lakeville, and Freetown.

THE TAUNTON CLAYS.

About 5 miles north of the morainal line passing through Middleboro is a belt of frontal deposits having the same general northeast-and-southwest extension. Along the southern front of the belt clays occur near Taunton. Brick clays are also worked at Titicut Station, in the valley of the Taunton River, near the railroad, midway between Middleboro and Bridgewater. The stratigraphic relations are not clearly exposed. The clays contain a few striated bowlders of small size and are probably continuous in the valley with the deposits at Taunton. Clays are also worked at Elmwood, north of Bridgewater.

RHODE ISLAND.

The glacial clays of this State, excluding those of Block Island, already referred to under the description of the New England islands, have a very limited exposure. Most of the lowland of the State is covered by widespread and deep sand plains, marking the successive stages in the retreat of the last glacial sheet. At a few points within the region skirting Narragansett Bay clays are known to occur. In many of the localities not enough can be observed to determine the geological position and relative age of the deposits.

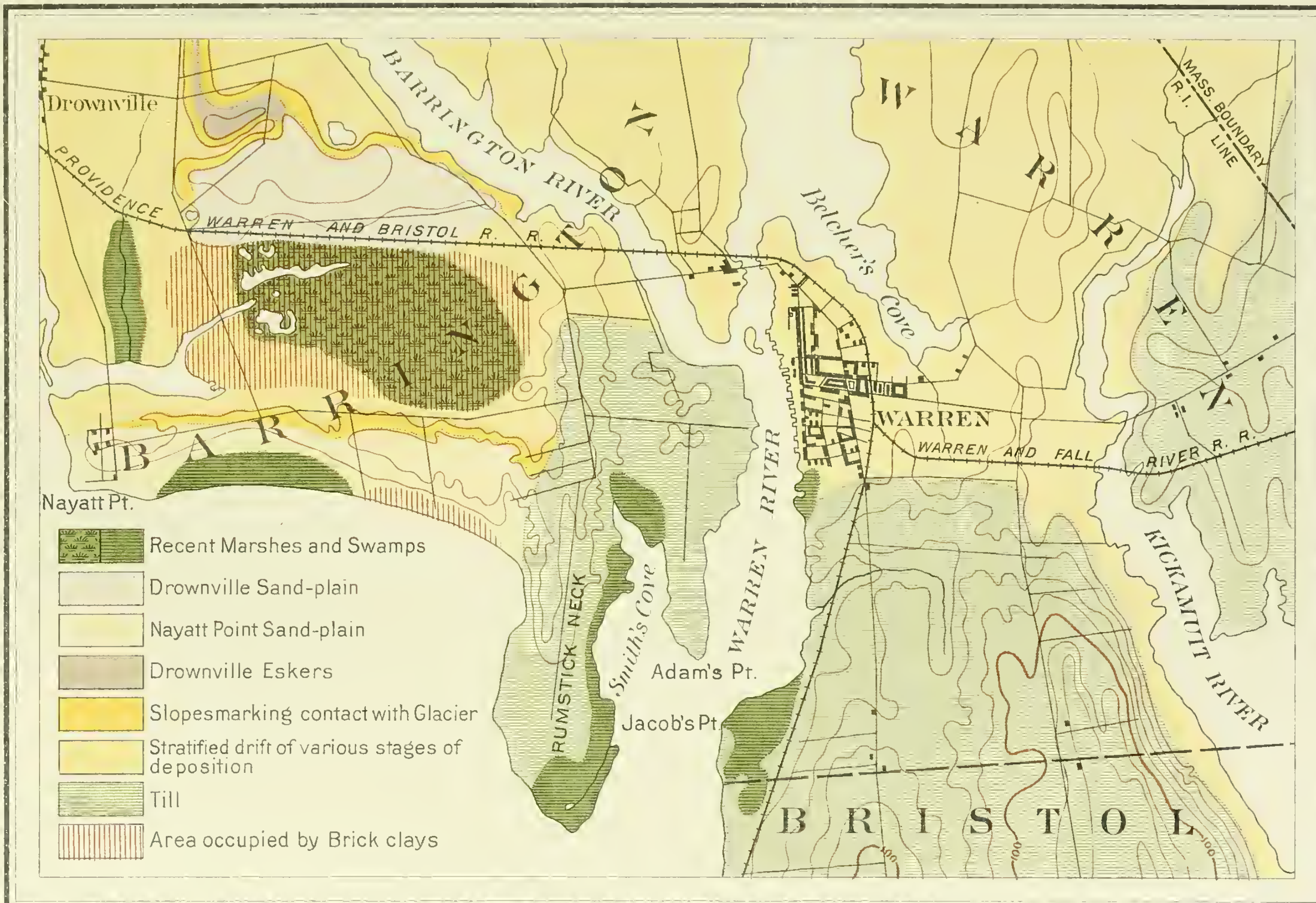
Ocherous, laminated clays crop out between high and low tide on the bay side of Bullocks Neck, opposite Rock Island. The clays are overlain by sands. East of Norwood, one-half mile south of the Pawtuxet River, along the road from Auburn, laminated clays were exposed in April, 1890. The upper surface of the clay formation is eroded, and resting upon it were 10 feet of sands of the sand-plain series. Three feet of the clays were exposed.

Beds of clay have been met with in wells sunk in and about Providence, but, in this district, clay is rarely found in strata more than a few feet thick. The clay is usually deeply buried by sands and gravels, and is mainly important in its natural site as an impervious layer controlling the distribution of underground water. The following record[1] of a well sunk near the corner of Angell and Wayland streets in Providence is typical for these clays:

Record of well-boring in Providence, R. I.

	Feet.
Sand, white, moderately fine	35
Sand, very fine and white (quicksand)	25
Sand, black, largely magnetic	2
Clay, blue, dense and compact	8
Gravel, blue, very coarse	Unknown.

[1] Providence Franklin Society Report, 1887, p. 98.



A. Hoen & Co. Lith. Baltimore

MAP OF BARRINGTON BRICK CLAY AREA

Pleistocene Geology by J. B. Woodward

Scale of miles

½ 0

CONTOUR INTERVAL 20 FEET

THE BARRINGTON CLAYS.

The principal occurrence of brick clays in Rhode Island is in the town of Barrington, in the area indicated on the accompanying detailed map of the Pleistocene geology. (See Pl. LXII.) The geological relations of the clays at this locality are tolerably clear. The area in which the clays are found is small, being between 1 and 1½ square miles only, and lying but a few feet above tide level. On its western side, in fact, the area is open to tide water and the clay pits are accessible by a canal to boats, which were formerly employed for transporting the finished bricks to Providence.

The clays are grayish to blue in color, and more sandy in their upper than in their lower courses. There appears to be, as at Middleboro, a passage from clays to sand in the top layer, a characteristic of those brick clays which have not been eroded by ice or other agencies. This featnre alone would perhaps be sufficient to show that the Barrington clays belong to the last glacial advance.

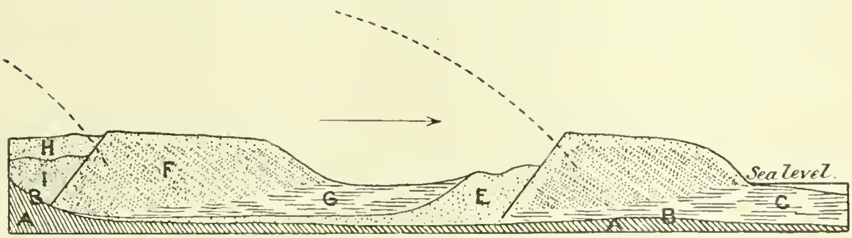


FIG. 36.—Section across Barrington, R. I., showing supposed relations of clays to glacial sand plains. A, Pre-Pleistocene terrane of Carboniferous age; B, place of glacial drift older than Nayatt Point stage of the retreating glacier; C, place of clays contemporaneous with the Nayatt Point sand plain; E, gravel and sands deposited on the surface upon the melting out of the ice along the head of the Nayatt Point sand plain; F, Barrington sand plain; G, Barrington clays; H, the esker; I, gravel and sands laid down upon the melting out of the ice back of the Barrington plain.

The workable depth of the clays is small, being limited by sea level. The Nayatt Brick Company is said to have sunk a well 65 feet through the clays, reaching at that level white gravel, and the clay beds at Barrington Station are reported to be 60 feet thick.[1]

The layer of sand, fine-grained and loose-textured, which tops the clays thickens northward toward the Barrington glacial sand plain, which rises mesa-like north of the railroad. Although there are no sections north of the railway exposing the geological relations of the sand deposit to the brick clays, there can be little doubt that the two are contemporaneous. The fact that the clays pass beneath the southern margin of the sand plain is a necessary result of the outward growth of the delta front of the plain upon the clays which were laid down at its margin when it was less extended in that direction. The general relations of these clays, which lie between two stages of sand-plain construction, are set forth diagrammatically in the accompanying ideal section (fig. 36).

[1] Providence Franklin Society, Report on the Geology of Rhode Island, p. 104.

THE BARRINGTON SPRINGS.

A local phenomenon of some interest as affecting the working of brick clays by keeping the bottoms wet is the occurrence of springs, or so-called "mud volcanoes," in the pits of the Barrington Brick Company. Here, on the floor of the clay pit, were to be seen, in 1894, several active minute cones, from 1 to 3 feet in diameter. Other very minute, steep-sided cones were not more than half an inch in diameter and of the same elevation. The larger cones were as much as 6 inches in height. At the apex, or on one side, where a shifting of the vent had occurred, was a shallow crater from 1 to 4 inches across, breached on one side by the excurrent stream of muddy water. The escape of gas was not detected by the eye. According to the statement of the foreman of the brickyards, these springs are active during the dry season of the summer, and have been known for years. Similar springs occur in the clay pits at Titicut, Mass.

These springs appear to differ from ordinary springs mainly in the quality of the solid matter discharged. The clay which they bring to the surface accumulates about the vent instead of being carried away, as is the case of the sand grains, however minute, in more freely flowing water. The sand plain on the north of the clay pits appears to act as a reservoir, the connection of which with the clay beds is formed by the fore-set beds of the delta (see F in fig. 36), which beds run out in the form of sandy layers in the clay section. In this way the rainfall percolating down through the sand is led into the clay strata along sandy partings, under conditions analogous to those which exist in artesian wells. Another explanation has been advanced by Shaler (see p. 971).

Period			(N.)	Economics.
	sin.	Cape Ann.	Northern New England	Brick clays.
	....	Marine erosion	....	Clays and marsh muds forming along coasts; not available deposits
	....	....	....	Possibly some coastal clays now elevated deposited at this time.
	.... l sand iation.	Frontal moraine.	Final disappearance of ice sheet.	Stony and bowlder clays of the uplands; till of drumlins; both locally used for brick making. Local deposits of clay in front of and under southern margin of glacial sand plains, usually sandy toward upper surface. Large areas of clay probably covered by sand and gravel plains.
	e sur-	Undetermined........	Not reported	No deposits recognized above sea level.
Pleistocene.	clays belong	Leda clays at Gloucester may belong here.	Undetermined.........	Deposition of much clay with bowlders dropped from floating ice.
	....	No evidence	No evidence	No deposits recognized above sea level.
	....	Wanting	Georges Banks and related elevations formed at this time?	
	f shells rumlins ix may	Not seen...............	Undetermined.........	Thin layers of clay interstratified with marine sands; of no commercial value.
	l........	Not seen...............	Not reported	No clays of this time as yet recognized in the area.

Correlation table of the Pleistocene deposits of Rhode Island and southeastern Massachusetts in relation to glacial brick clays, by J. B. Woodworth.

Chronology.				Local criteria.	Geographical distribution.									Economics.
					(E.) New England Islands. (W.)				(S.) Mainland. (N.)					Brick clays.
Period.	Epoch.	North America.	New England.		Nantucket.	Marthas Vineyard.	Block Island.	Long Island.	Cape Cod.	Narragansett Bay.	Boston Basin.	Cape Ann.	Northern New England.	
Pleistocene.	Recent.	Post-glacial	Present	Processes now in action ...	Marine erosion	Marine erosion	Marine erosion	Marine erosion	Marine erosion	Tidal action	Tidal action	Marine erosion	.	Clays and marsh muds forming along coasts not available deposits
			Terrace	Entrenchment of streams in valley trains and sand plains. Wind-drifted glacial sands; swamps, marshes, and peat deposits.	....	....	....	....	....	Poppasquash elevated beach.	....	......	.	Possibly some coastal clays now elevated deposited at this time.
	Glacial.	Third glacial	Champlain subepoch ..	Deposition of terminal and retreatal moraines, sand plains, eskers, kames, and moraine terraces. Time of retreat.	.... Terminal moraine	.... Terminal moraine	.... Terminal moraine	.... Inner moraine. Outer moraine.	.... Melting of ice blocks giving rise to ponds in frontal plains. Terminal moraine.	.... Providence plains. Barrington clays. Queens River moraine. Congdon Hill moraine. Charlestown moraine.	.... Eskers and sand plains. Drumlins. NNW-SSE striation.	.. Frontal moraine.	Final disappearance of ice sheet.	Stony and bowlder clays of the uplands; till of drumlins, both locally used for brick making. Local deposits of clay in front of and under southern margin of glacial sand plains, usually sandy toward upper surface. Large areas of clay probably covered by sand and gravel plains.
			....	Time of principal glaciation and advance. Erosion and striation.	....	....	....	....	....	....	N-S striation.			
		Second interglacial	Vineyard interval ...	Subaerial erosion on lands above present sea level; deposits below present sea level.	Unconformity at this stage; details of surface wanting.	Widespread subaerial erosion in highlands. Adjustment of stream valleys to folded structures; capture and beheading of streams.	Evidence of stream-carved surface, on which rests the last coating of glacial till.	Not surveyed	Unconformity; details undetermined.	Undetermined	Unconformable surface.	Undetermined	Not reported	No deposits recognized above sea level.
			Tisbury subepoch ...	Deposition of sands and clays with bowlders; land probably depressed 150 feet below present level at the close of this time.	Stratified sandy clays exposed beneath kame moraine probably belong here.	Stratified ferruginous sands with clays and bowlders in North Tisbury along Vineyard Sound. 150 feet thick above sea level.	Mohegan Bluff series: clays and sands with bowlders.	Not surveyed..	Stratified sandy clays at Highland Light and elsewhere. Probably fragments in "clay pounds" belong here.	Bullocks Point clays?	Mystic River clays probably belong here.	Leda clays at Gloucester may belong here.	Undetermined .	Deposition of much clay with bowlders dropped from floating ice.
		Second glacial		Erosion below present sea level. Land high.	Not seen	Unconformity at Gay Head and in North Tisbury.	Unconformity at Clay Head.	Not surveyed.	....	No evidence	No evidence	No evidence	No evidence .	
			Gay Head interval .	Folding and overthrusting of Cretaceous, Neocene, and earliest Pleistocene strata from Nantucket westward.	Observed at Sankaty and Squam heads in fossiliferous Pleistocene beds.	Profound inversion of soft strata over the island.	Inversion of beds at Clay Head.	Not surveyed..	Undetermined	Wanting	Wanting	Wanting	Georges Banks and related elevations formed at this time?	No deposits recognized above sea level.
		First interglacial	Sankaty subepoch	Compound gravels and sands, with local clay deposits. Post-Pliocene marine fauna. Beds involved in Gay Head diastrophe.	Coarse marine sands, with whole and wave worn shells. Post Pliocene fauna at Sankaty and Squam heads. Base not revealed.	Compound gravels and sands. Beds locally cemented by iron oxide. Locally carrying waterworn Miocene fossils.	Grayish compound gravels and sands involved in folds at Clay Head.	Not surveyed..	Undetermined	Not seen	Fragments of shells found in drumlins with matrix may belong here.	Not seen	Undetermined ...	Thin layers of clay interstratified with marine sands, of no commercial value.
		First glacial	....	Erosion of underlying terrane and transportation and deposition of bowlders of granitite, diorite, and peridotite (from Iron Mine Hill in Cumberland, R. I.) along lines traversed by drift of last Glacial epoch.	Not observed	Erosion of Pliocene and Miocene beds, and transportation of angular blocks of granitite, diorite, etc., up to 6 feet long.	Erosion interval between next above and Cretaceous (?) beds.	Not surveyed	Not seen	Not seen	Undetermined... ...	Not seen........ .	Not reported . ..	No clays of this time as yet recognized in the area.

CHAPTER III.

By C. F. Marbut and J. B. Woodworth.

THE CLAYS ABOUT BOSTON.

EXPOSURES.

Glacial brick clays are well developed in the estuaries of the Charles, Mystic, and Saugus rivers, north and west of Boston, Mass. Natural exposures of the beds are exceedingly rare. The top of the formation is in most places only a few feet above high-tide level, and often is below it. It has not been seen at more than 100 feet above sea level. Where above the sea, the clay is generally covered with stratified sand, with till, or with swamp deposits. The uneven surface of the brick clays thus indicated shows them to have a greater antiquity than has been generally recognized, and, taken in connection with the details presented in the following pages, serves to demonstrate the deposition of these beds prior to the formation of the drumlins and sand plains of the Boston Basin.

The most important exposures for geological purposes are those made by the brick manufacturers and those made in sewer construction. The pits at the large brickyards afford the best exposures of the clays; but as these are located where there is the least amount of overlying material, the result is that the stratigraphic relations of the clays to superjacent beds are not very well shown in them.

CHARACTER OF THE CLAYS.

The clays are of a bluish color, plastic, and consist of extremely fine material, which under the microscope is seen to be composed partly of quartz and feldspar and partly of material that is too fine in texture to give a distinct polarization color for each individual particle. It is probably disintegrated material instead of powdered rock. In thin, flocculent masses floating in water the whole has an amber-colored polarization, with the larger quartz and feldspar grains scattered through it, appearing as brightly polarizing spots.

The clays are generally horizontal and finely stratified, the layers being, as a rule, not more than 2 inches thick, and often much less. The alternations in the beds are due to considerable variations in the amount of sand which they contain.

Scattered through the formation are bowlders ranging in size from small pebbles to masses weighing several tons. The most abundant are about the size of a man's head. These bowlders usually display glacial striæ and surfaces smoothed by glacial attrition. Their presence in the clays seems best explained by supposing them to have dropped from floating ice during the deposition of the beds.

At a few points, notably in Cambridge, in sewer excavations, where the underlying Cambridge slates are near the surface, the base of the brick clays has been reached, or, at least, the clays have been observed to pass into a bowlder clay, essentially till in character.

The clay beds in North Cambridge are said by well borers to be from 82 to 85 feet thick and to be underlain by gravel. Borings in the city

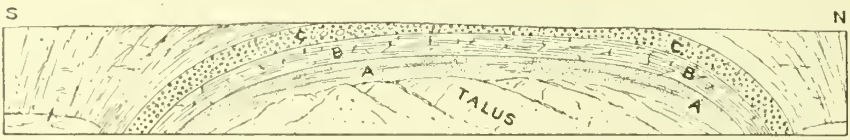


FIG. 37.—Sketch showing fold in brick-clay beds and associated gravels on the western side of Fresh Pond, Cambridge, Mass. From a sketch by J. B. Woodworth made in 1891. A, Fine sands, cross-bedded, with a few layers of clay; B, gray clay, similar to brick clays, with minute faults and joints, 10 feet; C, waterworn pebbles in coarse gravels.

of Cambridge have been reported in which beds of sand were intercalated between members of the clay formation.

The brick clays, though prevailingly horizontal, exhibit local disturbances on a scale relatively large as compared with the exposed thickness of the beds. These deformations are either in the form of folds or of disrupted masses and heads of clay protruding into overlying gravels. The section exposed in grading a road on the west side of Fresh Pond, in Cambridge, has revealed numerous instances of this displacement of the clays. The overlying kame gravels are also involved in folds in a way to show that the disturbance is a relatively late phenomenon, due to the last, and probably a local, advance of the ice. The accompanying section (fig. 37) exhibits a portion of the above-noted section.

In the North Cambridge clay pits folds also occur, but there is no evidence based upon the involution of overlying beds of the relative time of the disturbance. One such fold was visible in April, 1891, on the west side of Dublin street, in the form of a closed anticline forced over to the southward in a direction accordant with the hypothesis of glacial thrust acting upon the surface of these partially plastic layers (fig. 38).

SURFACE OF THE BRICK CLAYS.

The contour of the surface of the glacial brick clays in the region about Boston is still imperfectly known, but there are additional reasons to those already given for inferring that the general form of this buried topography is largely determined by glacial erosion. It is true that in the valleys of the Mystic and Charles rivers ordinary river and tidal processes have effectively acted to bring the surface immediately adjacent to the lines of the present drainage into a configuration peculiar to these agencies. The general horizontality of the clay beds and the mode of deposition of such fine materials make it necessary to suppose that when the deposit in this basin was in its original state its surface was approximately level or had such an inclination toward the deeper water as was determined by the nature of the bottom on which deposition began. The very considerable local inequalities in the surface of these clays is therefore explicable on either of three hypotheses—excavation, elevation by dislocation, or the transportation and accumulation of particles, as in glacial drumlins.

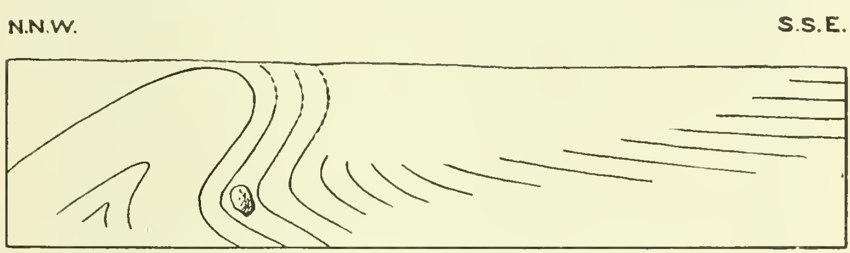


FIG. 38.—Overturned folds in West Cambridge brick clays.

The existing difference of level of the surface of the clays is as great as 40 feet within the limits of Cambridge alone.

Ice-worn surface of the clays.—At a number of points in Cambridge and Watertown where the morainal drift and the sands which cover the clays have been freshly stripped off the sharply defined upper surface of the compact brick clays has been exposed in the form of smooth, roundish ridges resembling very flat roches moutonnées. This form of erosion is well shown on the rising ground along the northern slope of the Cambridge moraine in the vicinity of Huron avenue. The phenomenon is indicative of the overriding of the clays by the ice.

CUBICAL JOINTING OF THE CLAYS.

The clays in the Cambridge pits in the upper 5 or 6 feet of the sections exposed are much checked by a rough cubical jointing. This secondary structure becomes more pronounced in the dry season, and is possibly due to contraction upon loss of water, though it may be owing to the effect of pressure applied by the once overlying ice sheet.

FROST MARKS ON CLAY BOTTOMS.

Wherever recently worked clay pits are exposed in the autumn in this latitude conditions prevail which favor the record of very transitory meteorological changes on their surface. After a shower raindrop imprints may frequently be observed upon the soft clay of partially dried-up pools. Frost marks in the form of ruffled, feathery surfaces also occur. Typical ice-crystal marks, formed by the impingement of acicular crystals of ice on the bottom or by their growth in the superficial layer of clay, frequently show the 30° and 60° angles peculiar to ice. Subsequent drying of the clay warps the surface and

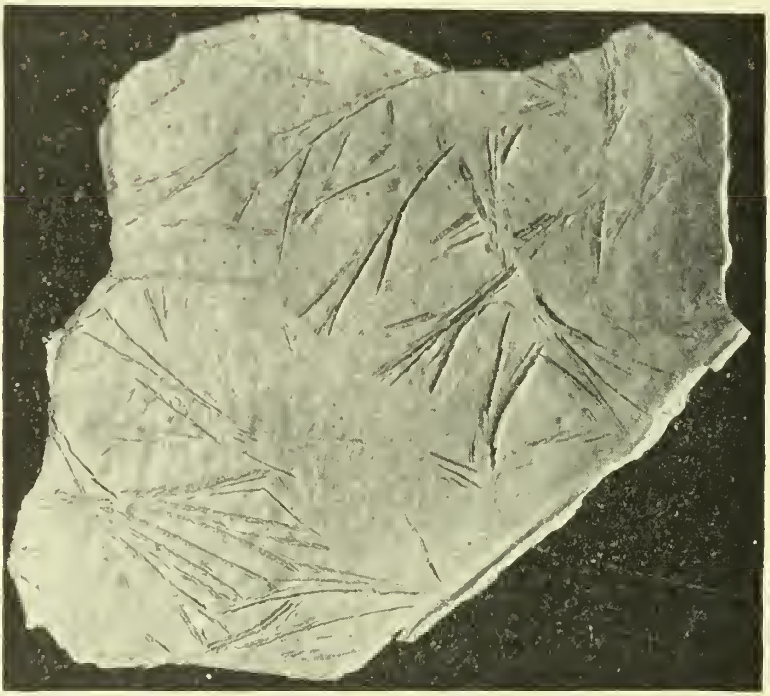


FIG. 39.—Ice-crystal marks. Clay pits, North Cambridge, Mass., Oct. 23, 1889.

slightly distorts these figures. Further desiccation of the clays may result in sun cracks following the lines of weakness determined by the course of the larger ice needles. (See fig. 39 for illustration of these imprints.[1]) These indications of exposure to the atmosphere are, so far as observations have determined, entirely absent upon the older surfaces formed successively with each layer of clay. These considerations therefore lead to the conclusion that the brick clays were uninterruptedly covered by standing water during the period of their deposition.

[1]See Hughes, T. M., On some tracks of terrestrial and fresh-water animals: Quart. Jour. Geol. Soc., London, Vol. XL, No. 157, 1884, p. 184. Describes ice-crystal plumes on mud and gives figures.

PRECEDING VIEWS ON THE AGE OF THE BRICK CLAYS.

The opinion that the clays described in this paper under the head of the Tisbury are older than the last ice advance is expressed, perhaps somewhat vaguely, in the writings of Edward Hitchcock as early as 1833, but his reasons for assigning to the deposits a Tertiary age were of a deductive nature rather than the result of a study of their inferior position in the field to the glacial drift which rests upon them. Although the clays were described by him under the head of Tertiary deposits, he expressed doubt whether they might not belong to the "diluvium" or drift. In 1841 he considered the clays "diluvial," being deposited "in every basin where the stirring diluvial waters were kept quiet by the surrounding hills." This conception, evidently true as regards their time relations to drift deposits now fully recognized as of glacial origin, has not been questioned by local observers.

CLAY STONES.

The nodules and stringer-like aggregations to which the term clay stones is properly restricted, the "clay dogs" of the clay workers, are less frequently found in this district than in the clays of the Connecticut Valley. The paucity of these consolidated portions of the clay beds in southeastern Massachusetts is probably due to the smaller amount of lime carbonate in the glacial waste of this field.

Imperfect clay stones were reported by Edward Hitchcock from the brick clays in the vicinity of Boston. In all the exposures made by workings within recent years these nodules are rarely found. In so far as they are wanting the clays are freed from one of the causes which frequently spoil the bricks made in the Connecticut Valley. Whenever the clays contain one of these calcareous nodules, its calcination results in the bulging out of the side of the brick or in the formation of cracks which unfit the baked piece for use.

Ring-shaped nodules are occasionally washed out of the clays in the banks of glacial lakelets near Boston, but little is known of their occurrence in clays resorted to for brickmaking.

FOSSILS.

The brick clays of the Boston Basin and the small separated deposits southward to the south coast have not afforded, so far as the Survey has been able to ascertain, definite traces of organic remains. The clays in Charlestown afforded Edward Hitchcock cylindrical casts from one-fourth to 1 inch in diameter which were considered by him as organic. These casts, in the form of minute tubes, with hardened walls, perforating the strata perpendicularly, are common at all depths in the Connecticut River clays accessible to examination. They appear to mark the path of percolating water charged with lime and iron salts, with which the walls and the permeable sandy layers were cemented. These pipes are not necessarily due to the presence of any organic form, though the formation of some of the cylindrical pipes in the upper parts of the clay pits may have been determined by the growth and decay of the roots of plants long subsequent to the deposition of the clays.

The fossiliferous fragments found in the drumlins about Boston indicate, by the nature of the matrix, that they are not portions of the brick clays, but their exact relations can be inferred only in the manner pointed out in the attempted correlation in the earlier parts of this paper.

ESTUARINE OR MARINE ORIGIN OF THE BRICK CLAYS.

The estuarine or marine origin of the brick clays in the Boston Basin has not been directly proved, but it is at least extremely probable. No marine fossils have been found in them, nor have they been traced continuously to a connection with clays carrying marine fossils. Their constitution shows that they were deposited in quiet water. Their positions show that they were laid down in estuaries which were open to the sea. There is no evidence that these water basins were shut out from the sea at the time of the deposition of the clays. The length of time required for the deposition of these slow-forming sediments is incompatible with the idea of ice barriers such as have been supposed to exist in the same region during the time of the formation of the overlying sand plains at a later stage in the glacial history of the region. Barriers of this nature are not sufficiently permanent. It is probable that the clays were more exposed then than now to the sea, for the reason that since the clays were deposited a great deal of till in the form of drumlins has been left upon their eroded surfaces, fending them off from the sea.

Moreover, the clays are deposits made in moderately deep water. This would require a submergence below the present stand of the land for all parts of the formation lying above the present sea level, making the supposition of a barrier to the estuaries still more difficult. The amount of this submergence about Boston has not been determined. Any beaches or erodible shore line features which may have marked this upper limit of the water in which the clays were deposited were probably effaced in the last advance of the ice. Benches cut in the hard rock on southward-facing cliffs may not have suffered that fate, but the connection of any such phenomena with the sea level of that time has not yet been recognized. The minimum amount of the submergence is indicated by the highest known occurrence of the marine clays. In the vicinity of Boston that occurrence is about 100 feet above the present sea level, but as in all the cases where the clays are observed their upper limit is determined by erosion, the submergence must have exceeded this amount.

INTERGLACIAL AGE OF THE CLAYS.

The clays were deposited in more or less direct connection with an ice sheet which had retreated across the area to a position north of the formation, and before a readvance of the ice. That the clays were deposited in connection with an advance of the ice is shown in their composition. They consist quite largely of ground-up rocks, and not of thoroughly disintegrated material. They also contain glaciated bowlders, some of which are too large to be carried by such ice flows as form at the present time on this coast.

That the brick clays are newer than at least one advance of the ice is shown by their resting on till at a few points in the vicinity of Cambridge. On the west side of Fresh Pond the clay bed in the section shown in fig. 37, though thinner than the beds elsewhere seen in the clay pits, is considered to be of the same series. It dips northward under overlying gravels and sands and appears beneath the level of the banks of the pond in a pit about 500 feet northeast of the locality shown in fig. 37. It then disappears beneath sands and gravels to reappear in a pit at a brickyard 400 feet northeast of the latter place. These three exposures are regarded as the same bed, on the

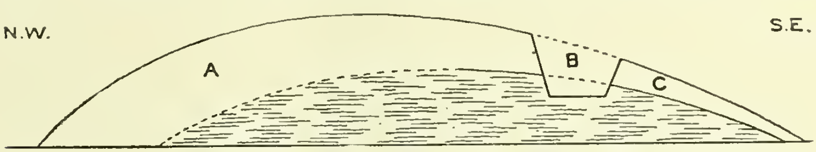


Fig. 40.—Section at Ten Pound Hill, Somerville, Mass., showing drumlin till overlying eroded surface of brick clays. A, thick cobbly till; B, road to Wellington; C, till with striated pebbles seen in clay-pit at this point.

ground of similarity in character and composition, and of continuity of stratification.

That the clays are older than at least one advance of the ice over the area is clearly shown in many localities. The stratigraphic evidence of this relation is more abundant than, and just as conclusive as, that for their being younger than one ice advance. One of the facts pointing to this conclusion is the occurrence of clay of the same physical character as the clays of the undisturbed beds in the till of the last ice invasion. Many of the drumlins about Boston Harbor contain a large amount of this clay, mixed up with gravel, bowlders, and the ordinary yellowish clay of the drumlins.

Another fact well established is that the clays underlie the drumlins. One of the localities where this relation is shown most conclusively is in the remnant of a drumlin known as Ten Pound Hill, at the southern end of the Wellington Bridge, in Somerville. The clays have been excavated beneath the salt marsh just south of the drumlin. In the drumlin itself the clays rise about 20 feet above the top of the clay in the neighboring marsh. At the southeastern end of the drumlin the plane of demarcation between the overlying gravelly till and the brick clays is sharply defined. Scratched pebbles occur plentifully in the till. Toward the northern end of the drumlin the till appears to be thicker and coarser and more commingled with clay. A cross section of the hill as it appeared in 1894 is annexed. The evidence goes to show the erosion of the clay surrounding the drumlin and the accumulation of till upon the same clay on the site of the drumlin.

Another significant locality is at the foot of the northern slope of Convent Hill, a drumlin, now largely removed, within the limits of Somerville, about 300 feet east of the junction of the Wellington road

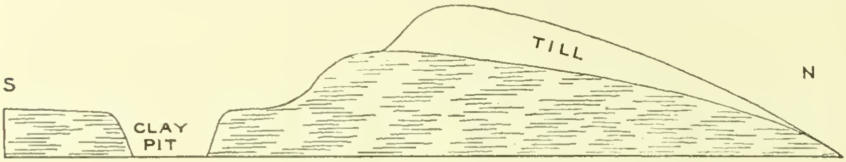


FIG. 41.—Cross-section at Ten Pound Hill, Somerville, Mass.

with that from Charlestown to Medford. A shaft was sunk at the foot of the hill in the autumn of 1894 in putting in a sewer. It was 33 feet deep when seen by C. F. Marbut, and was still in clay at the bottom. The clay has the same physical characters as that from the brick-clay pits. The slope of Convent Hill carried downward at the same angle that it has above the top of the shaft would cross the clay bed apparently several feet above the bottom. The relations of the till and clay, as interpreted by Marbut from the facts seen here, are shown in fig. 42.

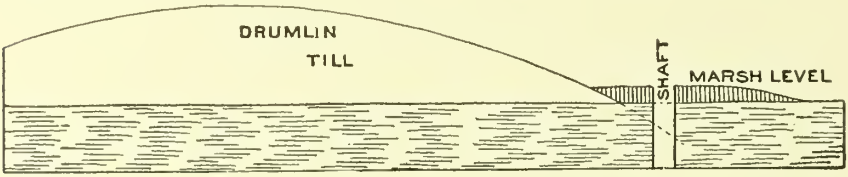


FIG. 42.—Diagram showing relations of brick clays and till at Convent Hill, in Somerville, Mass.

Another occurrence showing the same relation of till and clay beds is in Saugus, at a brickyard about 1,500 feet southwest of the railway station at East Saugus. The clay bed is now worked on the north face of th hill, just above the level of the salt marsh, where very little mate al overlies the clay. An old pit, now filled with water, about 200 fe t southeast of the present one and farther back in the hill, was operated formerly. In this place about 15 feet of till overlay the clay, which was found approximately at the same level as it exists in the present workings. The section at this locality is shown in fig. 43.

In the most of the clay pits in Revere the clays are worked up to the base of the drumlins and show no change in character nor diminution in thickness. The localities most frequently selected for a clay pit are not on the lowest points or midway between two drumlins, but as near to the base of a drumlin as possible without involving much stripping. The beds ought to be thinner here if the clays overlie the till of the drumlins, but in no case has a pit been seen which went to the bottom of the formation. The location of clay pits as near the base of the drumlins and as high up as possible is probably due to the better facilities for drainage in such situations.

Till was seen overlying stratified clays in Medford, Mass., in 1892 by J. B. Woodworth, on the east side of Winchester street, near No. 30, and south of Marion street, on the east side of the Boston and Lowell Railroad, and near old clay pits, in a ditch showing the following section:

1. Rich black soil, varying in depth from 12 to 18 inches.
2. Till, composed of subangular pebbles and cobbles, occasionally scratched, with a matrix of sand and some clay.
3. Brick clays, with a nearly level surface, but inclined slightly toward the pits on the east.

This till appears to be the peripheral, attenuated part of the mass which forms the drumlin of College Hill, the eminence on which stands Tufts College.

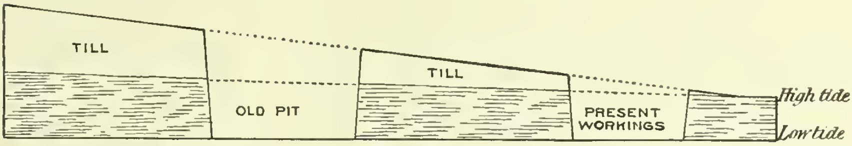


FIG. 43.—Section showing relations of till to brick clays in East Saugus, Mass.

In many places in Cambridge the clays have been seen within the last few years in excavations for sewers. The clays are in all cases overlain by a bed of stratified sand of varying thickness. They are known to occur under the Museum of Comparative Zoology, overlain by about 10 feet of stratified sand. These clays on the south side of the ridge running from Cambridge Station westward to the south side of Fresh Pond, are evidently a part of the formation which lies on the north side of the same ridge, and which, indeed, enter into the formation of the ridge itself.

The same relation of the clays to overlying stratified glacial sands is shown near East Everett Station, where the sand is about 2 feet thick, overlain in turn by about 1 foot of salt marsh.

The sand flat extending over a considerable area south of Medford and northwest of Wellington Station is underlain apparently everywhere by the clay formation. In all the clay pits in this vicinity the sand varies from 3 to 10 feet in thickness. In the salt marsh half a mile west of Wellington Station are the stumps of many cedars or pines that grew in the sands overlying the clays before the invasion of the area by the marsh.

OLDER PLEISTOCENE DEPOSITS OF BOSTON HARBOR.

Professor Crosby and Miss Ballard find evidence in the fossiliferous drift in the drumlins of Boston Harbor of a succession of ice advances.

When the ice sheet first invaded this area the shells on the bottom of Boston Harbor were reduced to fragments and became a part of the ground moraine or till. During the recession of the ice sheet the till was locally cemented or lithified by carbonate of lime derived from the shells through the solvent action of meteoric waters, the still undissolved shells thus becoming, in some cases, completely inclosed in a firm matrix. During the second advance of the ice sheet the shells suffered further comminution, and the cemented or lithified portions of the till were more or less broken up and abraded or glaciated.[1]

The authors of the paper above referred to, however, feel constrained to state that they find no evidence of an interglacial period.

The time of building these fossiliferous fragments into the drumlins having been obviously the last Glacial epoch, that of the formation of the earlier fossiliferous till fragments succeeded the deposition of the shell beds, the time of which can also be approximately determined. A comparison of the species found fossil in these fragments with the Sankaty Head fauna makes it a probably correct inference that these shells are of the same age, there being at least 27 identified species in common, but these are mainly living in nearby waters. The Sankaty beds on Marthas Vineyard and Block Island are succeeded by the Tisbury beds, the genesis of which seems best explained by a time of ice action, if not actual glaciation, and all of this long anterior to the last Glacial epoch, which was separated from the Tisbury epoch by the relatively long Vineyard interval. The evidence as to the succession of events in the New England islands and in the Boston Basin is thus essentially parallel.

[1] Distribution and probable age of the fossil shells in the drumlins of the Boston Basin: Am. Jour. Sci., 3d series, Vol. XLVIII, 1894, pp. 494-495.

CHAPTER IV.

By N. S. Shaler.

ECONOMIC RESULTS AND SUMMARY.

Although the inquiry the results of which are set forth in the preceding pages of this memoir was not made especially with the intention of determining the economic conditions of the clays of the region studied, certain information of value to those who are commercially interested in these deposits may be here given; a brief statement will therefore be made of facts which may be serviceable to those who are seeking to utilize the clays of southeastern New England.

The observations set forth in the preceding pages show that the valuable clays of this district are industrially divided into three groups which agree tolerably well with the classes in which they are placed by their geological history. There are the Cretaceous and Tertiary, the earlier Pleistocene, and the last Glacial.

CRETACEOUS AND TERTIARY CLAYS.

The Cretaceous and Tertiary deposits include only the beds which are developed on Marthas Vineyard and possibly on some other of the New England Islands. For economic purposes they may be regarded as limited to the western half of Marthas Vineyard. They contain a considerable variety of clays, which differ much from one another in physical properties and in fitness for use in the arts. In general characacter they resemble the well-known clays of New Jersey. Some of these clays of Marthas Vineyard are by their quality better suited for making the more valuable kinds of pottery than those from any other deposits found along the Atlantic Coast, and if they were not very ill placed for use they would doubtless have already been extensively exploited. As it is, the dislocated character of the beds, which are everywhere steeply tilted and often much broken up, makes it difficult and costly to use the materials from the valuable layers, which are entangled with those that are worthless. The only place where the beds are so exhibited as to guide in exploitation is in the cliffs of Gay Head, where the deposits are well shown, but they are there so complicated by folds, faults, and shearings that it has been found impossible to follow them by such large and systematically arranged workings as are necessary for economically good results. There seems little reason to believe that in any part of the island where these clays lie above the level of the sea—an area of about 30,000 acres in all so lying—the beds are much less disturbed than at Gay Head. We may therefore assume that the same difficulties which have been encountered at places where the beds are well exposed will in an even greater measure be met where they are hidden by the soil and the underlying glacial drift. Moreover, the part of the island where these clays are accessible is quite without harbors. Vessels have to take their cargoes from wharves on a coast which is exposed to heavy storms, and which is accessible with safety for only a part of the year, and then only in quiet weather.

The result of these conditions, which the senior author has had an opportunity carefully to note for the last ten years, is that, notwithstanding the excellence of the Marthas Vineyard clays and the long time that their quality has been known, they have never come into general use. Several extensive and well-conducted experiments in shipping the material or in using it for various purposes on the ground have ended in failure. The only evident means of utilizing the deposits would seem to be by turning them to account in small factories producing articles of pottery which might have a peculiar value on account of their decoration or finish. The conditions seem unfavorable for the utilization of the materials in the manufacture of brick, paints, or ordinary pottery, where the cost of the material is a determining factor in the business. A large establishment for making brick on the north shore of the island came to ruin. Another on the same shore, where the clays were ground and lixiviated in order to prepare them for use in manufacturing oilcloths, has been allowed to fall into decay. The surface, which is underlain by the whiter clays, is dotted over with pits, where at various times within the last half century unsuccessful efforts have been made to win a profit from the deposits.

It is possible that further search beneath the drift covering of Marthas Vineyard will reveal the existence of areas in which the clay beds may be in such positions that they can be worked under favorable conditions. In this improbable event, and with a harbor provided, as it could be at a relatively small cost at Menemsha Pond by cutting a passage through the sand beach, these clays might be advantageously marketed.

PLEISTOCENE CLAYS.

The Pleistocene clays, those formed after the disturbances which folded the older deposits of Marthas Vineyard had taken place, are extensively developed throughout the islands and the seaboard district of southeastern Massachusetts As noted in the earlier sections of this paper, these clays are widely distributed. They occur plentifully on the New England Islands, on Cape Cod, and elsewhere beneath the deposits of the last ice epoch. In character they generally resemble the clays last formed in this district, being of that uniform quality which fits them for use solely in making brick or for the rougher kinds of tile and pottery work. As a whole they contain more iron than the newest clays of this part of the country. They shrink and warp more on burning, and are therefore less suited for the arts than the last-named group. It is possible that this group of argillaceous deposits, newer than the Tertiary but older than those formed during the last Glacial epoch, may be made fit for use if mingled with other materials, but in their unmixed state they must be regarded as of less promise than those of the other groups. So far as known, the only place where these clays are now exploited is in the town of Sandwich, on Cape Cod, where a brickyard has its pits in a deposit which probably is of this relatively early age. As yet the operations are not of sufficient extent clearly to determine the full value of the beds. The establishment for brickmaking at Roaring Brook, on the north shore of Marthas Vineyard, which worked clays of this age, found difficulty in obtaining products of satisfactory quality. The trouble appears to have inhered in the nature of the clay. It may be observed, however, that the material from Cape Cod is much more nearly like the newer deposits, which are next to receive our attention. It may therefore be found that these more northern deposits will prove quite suitable for use in the arts.

The only notable economic value of the clays of the group we are now considering has been found in their application to the sand roads of Cape Cod. In this district, where the stratified sands of glacial origin and those which have been blown inland from the beaches are alike extensively developed, the only available resource of the road masters in their efforts to better the highways has been to apply a coating of this clay to the surface of the road. Laid on to the depth of 3 to 6 inches, the material quickly works down into the sand and serves to bind it with tolerable firmness. For a year or two after the layer is applied the benefit continues, but gradually the adhesive matter works downward or is blown away, so that the effect is impermanent. In many cases this process of repairing ways is so costly that it is cheaper to harden the trodden part of the road with broken stone brought from a distance than to incur the expense of repeating the application of clay at intervals of a few years. Still, for local ways this method of repairing is commendable.

If the clay deposits which probably underlie the greater portion of the Cape Cod district were not in most parts of that area either below the sea level or so deeply covered with glacial drift as to be inaccessible, a much more extended use of the material in bettering the roads would have been made than has been the case. In fact, however, these clays, with rare exceptions, are accessible only where they occur in the form of masses, often of large size, which have been forced above their original position and mingled with the drift. In other cases the deposits appear to consist of sharp ridges of the clay, which were left projecting much above the general surface by the erosion that took place before the last ice epoch, and which are now mantled over by the drift envelope. Neither of these sources of clay affords good opportunities for obtaining a cheap supply of the material.

The latest group of clays, those commonly used for making brick in New England, were formed during the retreat of the glacier during the last ice epoch of this part of the country. Where the ice lay beyond the present line of the shore, and while the erosive work which it did was most intense, the clays derived from the fine muds which escaped from the subglacial mass were deposited, doubtless in large quantities, far to the seaward of the existing coast. As the front of the ice in its waning period, with occasional readvances, retreated to the northward the mass thinned and the wearing which it effected on the bed rocks diminished, and thus smaller and local deposits of clay were formed. These limited clay fields, as has been noted by Mr. Woodworth, appear to have been built near the mouth of each of the subglacial rivers. This conclusion is attested by the fact that many of these clay deposits lie approximately a little beyond the point where for a time one of these streams, escaping from beneath the ice, left marks of its action in the form of deltas, which are still traceable. We thus not infrequently find in elongated ridges of sand and gravel the molds of the caverns through which were discharged the waters of the subglacial streams that carried the clays out into the sea. Beyond the southern ends of these eskers there generally extends a sand plain with an approximately level surface. Experience shows that yet farther away from the old margin of the ice, but sometimes beneath this plain, clay deposits are likely to be found. It may in general be assumed that wherever considerable plains of sand occur in the valleys of southeastern New England there is a fair chance that clay beds exist beneath or near the covering. It must not be assumed, however, that where they exist they will in all cases be found at depths economical for working. Nor should it be supposed that the clays are altogether limited to the regions beneath the sand plains. The deposits formed before the last advance and retreat of the ice are, as noted in the early part of this paper, not infrequently covered by other forms of drift, but in these cases the nature and depth of the superincumbent material are likely to be such as to make it too expensive to work them.

So far as the facts have been gathered they go to show that no available deposits of clay exist in the region under discussion at a greater height than about 100 feet above the sea level. It seems tolerably safe to assume that south and east of a line extending from the mouth of the Merrimac River to Stonington, Conn., there is not much chance of finding considerable deposits of clays fit for brickmaking at higher levels than have just been indicated. In this field the beds of value are in the main limited to the valleys of the greater streams, probably for the reason that the existence of such valleys, which were formed before the advent of the glaciers of the last ice age, determined to a great extent the paths which were followed by the rivers that coursed beneath the ice, bearing forth the finely ground rock that went to form these deposits.

It is to be noted that the clays of the southeastern section of New England, taken as a whole, exhibit a greater range of features, chemical and physical, than those of any other portion of the eastern United States. As yet their properties in relation to the industries have not been carefully determined. It is quite likely that a well-conducted inquiry would show that the range of possible applications of these materials is much greater than has been supposed. It is especially desirable that this study should include the group of clays which are later than the Tertiary and older than the deposits formed during the last Glacial epoch. It is also important that the result to be attained by mixing the several varieties of clay, including those which are found in the Cretaceous and Tertiary deposits of Marthas Vineyard, should be inquired into. Consideration should also be given to the use of the very siliceous beds of Marthas Vineyard, which may, perhaps, with or without preliminary treatment or admixture with other materials, prove to be well suited for making fire bricks.

In closing, it may be well to remark that the coals of the Rhode Island and Massachusetts basin, which may be obtained without undue cost about Narragansett Bay, appear to be tolerably well fitted for use in burning brick in kilns. If this should prove to be the case, a fairly cheap fuel would be provided in the immediate neighborhood of the clay deposits which have been mentioned in this paper.

SUMMARY AND CONCLUSION.

From the purely scientific point of view, the most important point which it has been the intention to develop in this paper concerns the divisions of the so-called Glacial period into three great epochs of ice action separated from one another by very long intervals. In the opinion of the senior author, the interval between the first and the third of these periods was many times as long as that which has elapsed since the ice passed away from this district. This, as has elsewhere been noted, is indicated by the facts that the beds containing glacial erratics underlying the island of Marthas Vineyard were folded, and that the stream erosion which took place in that interval resulted in the development of a complete and extensive topography, well organized in relation to the understructure and far advanced toward base-leveling, with reliefs of as much as 300 feet, before the last advance of the ice occurred. Since the departure of the ice, which in its last forward movement altered in no considerable way the surface over which it passed, the surface of that island, except for the encroachments of the sea, has undergone very little change.

As for the division of the work of erosion done between the first and the third ice advance, the evidence is not so clear. It is evident, however, that the Weyquosque series, at least that division of those beds which Mr. Woodworth has in this paper termed the Sankaty beds, was laid down before the orogenic movements which have so profoundly affected the district were ended, and that the Tisbury beds were deposited on the northern shore in some parts of the valleys of the island. To the senior author it seems probable that the second Glacial period did not result in the actual erosion of the area by the glacier to any considerable amount, but only in the deposition of certain beds of material which can not well be explained except by glacial conditions. In fact, the gravels, sands, and clays from the base of the Weyquosque to the close of the last ice epoch can be accounted for only on the supposition that they are due to ice work.

On the whole, the evidence inclines one to the opinion that the greater erosion, and presumably the longer interval, was between the second and third advances of the ice, but there is as yet no basis for any accurate determination of the length of time which elapsed between the first and second epoch. It may be noted that the evidence as to this interval is almost altogether limited to the facts afforded by the island of Marthas Vineyard. There only do we have access to deposits which contain large erratics, transported from a distance of 40 miles or more, lying in beds which have been disturbed and afterward eroded by the streams in the manner above described.

THE COLUMBIA FORMATION.

It will be observed that no effort has been made to correlate the deposits which are considered in this writing with those of the Columbian age as described by McGee in the more southern parts of the eastern United States. Although this inquiry is obviously important, it has been deliberately put aside for the present, for the reason that before results of value can be obtained it will be necessary carefully to study the deposits of Long Island, New York. A preliminary view of the problem leads to the alternative suppositions that the Columbia formation may be the southern equivalent of the Weyquosque beds or that it may represent the marginal deposits formed during the time when the first two advances of the post-Tertiary glaciation took place. As may be seen from this paper, it is not easy, even in the mainland portion of southern Massachusetts, to discriminate in all cases between the beds which were formed during the first and those formed during the second ice period.

THE FAUNAL RELATIONS OF THE EOCENE AND UPPER CRETACEOUS ON THE PACIFIC COAST.

BY

TIMOTHY W. STANTON.

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THE FAUNAL RELATIONS OF THE EOCENE AND UPPER CRETACEOUS ON THE PACIFIC COAST.

By Timothy W. Stanton.

INTRODUCTION.

In most regions each of the great geological systems is easily separated from those that immediately precede and succeed it by notable changes in the life, by marked lithological differences, or by structural breaks, such as angular unconformity or other evidences of a period of uplift and erosion. When, as is often the case, the three kinds of changes coincide, the structural break, attesting a long interval with its attendant disturbances of land and sea during which there was no sedimentation in the area involved, is sufficient explanation of the changes shown in life and sediments when the sea again returned. In Europe and in many other parts of the world the line between the Cretaceous and the Tertiary is especially well marked. On this subject Professor Kayser[1] says:

> There is scarcely any other division in the history of the earth which is so important and so natural as that between the Chalk and the Tertiary. This is connected with the fact that at the close of the Chalk age a change took place both in the distribution of land and water and also in the development of organic life—so great and universal that it has scarcely been equaled at any other period of the earth's geological history.

To believe that this change really was universal and contemporaneous over the whole earth would be inconsistent with the generally accepted uniformitarianism of modern geology and biology, though the possibility may be admitted that such a change might involve all the present land areas, and thus be practically universal, so far as accessible records are concerned. No further argument is needed on the general question of continuity of sedimentation since Lyell's masterly presentation of it. On the special case now under consideration, he remarks:[2]

> Whether we shall ever succeed in like manner in diminishing greatly the hiatus which still separates the Cretaceous and Eocene periods in Europe can not now be

[1] Text-book of Comparative Geology, translated by Philip Lake, London, 1893, p. 326.

[2] Principles of Geology, 1st American from the 6th English edition, Boston, 1842, Vol. I, p. 298.

foreseen, but we must be prepared to expect, for reasons before stated, that some such chasms will forever continue to occur in some parts of our sedimentary series.

Since Lyell's time the extension of geological investigation over much larger areas and the more thorough collecting and study of the fossil faunas and floras have more or less completely filled many of the gaps that were known to him. Numerous modern types of life have been traced much farther back in geological history, and other types that have become extinct have been found to continue into later periods than those that were once supposed to be their limit. Series of strata have been found in which the evidences of age usually relied upon seem to be conflicting, one line of investigation causing a reference to one period while a study from another direction seems to indicate an earlier or later age.

The principles of Lyell were soon formally accepted by almost all geologists, but there was an apparent reluctance in most cases to make a practical application of them. For example, when the great series of fresh and brackish water beds usually known collectively as the Laramie was first studied, it was assigned by different investigators as a whole to the Cretaceous or to the Tertiary, the assignment depending on the relative value accorded to the animals, the plants, and the facts of stratigraphy as then understood. It was only after several years that the idea gained many adherents that the Laramie might belong in part to both systems. Similarly, when the geologists on the Pacific Coast found a series of marine beds known as the Chico and the Tejon on the confines of the Cretaceous and Tertiary which in their opinion showed a continuity of deposition and of life, they assumed that the entire series must be either Cretaceous or Tertiary, and each investigator assigned it to the one or the other, according as he had seen more of the lower or the upper portion. In recent years, however, the fact that both Cretaceous and Eocene are represented in the Chico-Tejon series has been generally accepted, and it has been emphatically asserted that there is both faunal and stratigraphic proof of a gradual transition from one system to the other.

It is my purpose in the following pages to examine the evidence that has been offered to prove such a transition, especially that furnished by the invertebrate faunas, and to determine, if possible, whether the faunas are really so closely related as to be accepted as proof that they belong to an indivisible series.[1] There can be no question that life was somewhere continuous from the Cretaceous into the Eocene, but that it was continuous in any particular region requires adequate proof to be accepted.

[1] In 1888 Prof. Angelo Heilprin gave an excellent critical review of the same general question, which will be discussed on a subsequent page, and which has been of great value in my studies. His conclusions, drawn from the examination of the literature and a part of Gabb's Tejon collections, are essentially confirmed by my study of new collections from many localities and of the field relations at some of the more important places.

HISTORICAL REVIEW.

The first determination of the age of any part of the Chico-Tejon series was made by Conrad[1] in 1855, when he described a few species of fossils from the neighborhood of Fort Tejon, in southern California, and referred them to the Eocene. He especially mentions the occurrence of *Cardita* (*Venericardia*) *planicosta* and two other species that he regards as identical with forms from the Claiborne beds of the Alabama Eocene.

In the following year Trask[2] published a paper entitled "Description of a new species of Ammonite and Baculite from the Tertiary rocks of Chico Creek," thus attributing exceptional characters to the Tertiary faunas of California. The rocks were supposed to be at least as late as the Upper Eocene, on account of the large proportion of recent genera found in them, but they are now known to be Cretaceous, and this must be regarded as the typical locality of the Chico group, to which it gave its name. The supposed Tertiary affinities of some of the fossils will be discussed beyond.

The Chico Creek occurrence was mentioned soon afterward by both Blake[3] and Newberry.[4] The former thought that the beds were Miocene, and mentioned the occurrence there of two species—*Nucula divaricata* Conrad and *Mactra albaria* Conrad—that had been described as Miocene from Astoria. These identifications were both incorrect, as Newberry, who argued for the Cretaceous age of the deposits, supposed.

The description of any considerable portion of the faunas was begun by Gabb in 1864 with the publication of Paleontology of California, volume 1, in which Conrad's Eocene fossils from Fort Tejon and others from the same horizon were referred to Division B of the Cretaceous, and all the beds now known as Chico, Horsetown, and Knoxville were grouped together as Division A of the same system. The species that Conrad had identified with eastern Eocene forms were considered distinct and were renamed. In the preface (p. xix) Whitney states, on the authority of Gabb, that the lower division "has yielded 150 species in California out of about 260 collected in the Cretaceous, and of these only about half a dozen are common to this and the upper division (Division B)." No formal discussion of the age of the upper division, nor reasons for referring it to the Cretaceous, are given either in this report or in Whitney's[5] volume published in 1865. Conrad's criticism,

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[1] Pacific Railroad Reports, App. to Prelim. Geol. Rept. of W. P. Blake, Paleontology, pp. 5–20. Reprinted in Pacific Railroad Reports, Vol. V, part 2, pp. 317–329, Washington, 1857.

Previously, in Dana's Geology of the Wilkes Exploring Expedition, pp. 611–678, Conrad had described a collection of fossils from Astoria, Oreg., as Miocene. He afterward referred them to the Eocene, and Dall has since shown that both horizons are represented there.

[2] Proc. California Acad. Nat. Sci., Vol. 1, pp. 85–86.

[3] Pacific Railroad Reports, Vol. V, part 2, pp. 173, 188.

[4] Idem, Vol. VI, part 2, pp. 24–25.

[5] Geol. Surv. California, Geology, Vol. I.

however, called forth a long discussion between him[1] and Gabb,[2] in which the arguments against and for the Cretaceous age of these upper beds were fully given. Conrad insisted on the Eocene character of the fauna, as shown by species identical or closely related with characteristic forms of the Atlantic and Gulf border Eocene, and he suggested that the presence of a few Cretaceous species, if any such really were found with the Eocene fossils, was due to accidental mixing by transportation and redeposition from previously existing beds.

Gabb, on the other hand, maintained that the Cretaceous age of the upper division was proved by the occurrence of Ammonites in its upper portion, by the presence of a number of other exclusively Cretaceous genera, such as Gyrodes, Margaritella, Anchura, and Perissolax,[3] by the possession of a considerable number of species in common with Division A, which is unquestionably Cretaceous, and by the discovery of "a locality near Clear Lake * * * where within a space of 2 feet I found an admixture of upper and lower forms, proving the existence of a transitionary bed, or perhaps group of beds."[4] His statements concerning the number of common species are somewhat inconsistent. In one place he says: "Of 280 species of fossils recognized and named in the California Cretaceous rocks, 107 are found in this upper member. Of these, 84 are peculiar and 23 are found in common between undoubted members of this group and undoubted members of the older group." But statements elsewhere show that 7 of these 23 species were not known from older beds than the "intermediate beds" at Lower Lake just mentioned.

In 1869 the second volume of Palæontology of California was published, in which the number of species was augmented by the description of new forms, but the number of species common to the two divisions was not increased. Whitney's preface to this volume gives a more refined classification of the Cretaceous rocks of California, as follows:

1. Division B of the earlier report was named the Tejon group. "This group contains a large and highly characteristic series of fossils, the larger part peculiar to itself, while a considerable percentage is found extending below into the next group and several species still farther down into the Chico group. Mr. Gabb considers it as the probable equivalent of the Maestricht beds of Europe."

2. "The Martinez group is proposed provisionally to include a series

[1] Am. Jour. Conchol., vol. 1, 1865, pp. 362–365; vol. 2, 1866, pp. 97–100. Smithsonian Misc. Coll. No. 200, Check List of Invertebrate Fossils of North America: Eocene and Oligocene, p. 37. Am. Jour. Sci., 2d series, vol. 44, 1867, pp. 376–377.

[2] Am. Jour. Conchol., vol. 2, pp. 87–92. Am. Jour. Sci., 2d series, vol. 44, 1867, pp. 226–229. Proc. California Acad. Nat. Sci., Vol. III, 1867, pp. 301–306. Geol. Surv. California, Paleontology, Vol. II, 1869.

[3] Probably none of these genera, excepting possibly the last, really occurs in the Tejon. As Conrad showed, *Perissolax blakei* is closely related to his Eocene genus, Levifusus, and Meek stated that Gabb's species of Margaritella belong to Solariella. In Vol. II, Palæontology of California, no species of Anchura is mentioned from the Tejon, and the only occurrence of Gyrodes above the Chico is in the intermediate beds near Lower Lake.

[4] Proc. California Acad. Nat. Sci., Vol. III, p. 302.

of beds of small geographical extent, found at Martinez and on the northern flank of Monte Diablo. It may eventually prove to be worthy of ranking only as a subdivision of the Chico group."

3. The Chico group was made to include all the other Upper Cretaceous beds of the Pacific Coast.

4. The name Shasta group was proposed for all the Cretaceous beds beneath the Chico. "It contains fossils seemingly representing all ages, from the Gault to the Neocomian, inclusive, and is found principally in the mountains west and northwest of the Sacramento Valley."

In the description of the species Gabb still speaks of the "intermediate beds," and refers to them fossils from localities near Lower Lake, Martinez, and Clayton.

The first suggestion that the Tejon might be a transition series resulting from continuous sedimentation from the Cretaceous into the Eocene seems to have been made in 1874 by Cooper,[1] who published an article entitled "The Eocene epoch in California—Are there really no Eocene strata?" In the same year Dana published the second edition of his Manual of Geology, in which the Tejon is referred to the Eocene.

Marcou[2] discussed the age of these beds in 1876 and considered both the Chico and the Tejon to belong to the Eocene, and the same views were repeated in a later paper, entitled "Note sur la geologie de la Californie."[3] He says that "Ammonites, Baculites, Helicoceras, etc., continued to live in the Tertiary seas of the Pacific region when these genera no longer existed in the Atlantic hemisphere."

In 1882 Heilprin[4] announced that in studying a part of Gabb's collection of Tejon fossils he had found a fragment of an ammonite "embedded in a rock fragment belonging to the so-called Tejon group of Fort Tejon, Cal." He held that the ammonoid, which was not generically determined, was a real member of an Eocene fauna. In the same volume Newberry[5] commented briefly on Heilprin's note, and protested against calling the Tejon Eocene, saying that "there are many species common to the Tejon and Chico groups, and where one goes the other must follow." Heilprin continued the discussion by publishing an important critical review[6] "On the age of the Tejon rocks of California and the occurrence of ammonitic remains in Tertiary deposits," in which he set forth all the evidence that had been offered for the Cretaceous age of the Tejon, and decided that it was insufficient to offset the Eocene character of the larger part of the fauna. He showed that even if Gabb's statements concerning species common to the Tejon and underlying beds are accepted as accurate, the faunas can not be regarded as very closely related.

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[1] Proc. California Acad. Nat. Sci., Vol. V, 1874, pp. 419–421.

[2] Ann. Rept. Geog. Surv. West 100th Merid., for 1876. pp. 167-169.

[3] Bull. Soc. géol. France, 3d ser., Vol. XI, 1883, pp. 407-435.

[4] Proc. Acad. Nat. Sci. Phila., vol. 34, 1882, p. 94.

[5] Pp. 194–195.

[6] Ibid., pp. 196–214. Reprinted in Contributions to Tertiary Geology and Paleontology of the United States, pp. 102–117, Philadelphia, 1884.

In 1885 White[1] discussed the age and relations of the Chico-Tejon series, the two names being thus united for the first time to express his idea of the close connection of the fauna and strata. His principal conclusions are summarized in the following paragraph:

Since in all other parts of the earth where Mesozoic and Cenozoic strata have been fully studied, the boundary, both faunal and stratigraphical, between the Upper Cretaceous and Lower Tertiary has been found to be well defined, many persons, apparently regarding that condition as the normal or natural one, have believed that the commingling of the Tertiary and Cretaceous types, which was shown by Gabb's publications, really did not exist in nature, but that it was due to some accidental or adventitious causes. While the commingling of Cretaceous with Tertiary types in the same strata probably does not exist to as extreme a degree as seems to be indicated in some of Mr. Gabb's earlier writings, I am satisfied that such a commingling does exist to a large extent, and that an alternate commingling of species exists throughout the whole of the Chico-Tejon series. That the upper part of this series is almost purely of Eocene character and that the lower part is as distinctly Cretaceous is, I think, undeniable. Still, I am satisfied that no definite horizon exists in that series which will separate all the Cretaceous from the Tertiary, and that no lines can be drawn which will separate a median portion of the series in which all the commingling of types takes place.

The region about New Idria, Cal., is cited as presenting the "most satisfactory illustration of the intimate stratigraphical connection between the Chico and Tejon groups," but no commingling of the faunas was observed there, and very few fossils were obtained from the Chico. He states, however, that—

The exact equivalents of this New Idria series of rocks are found in the vicinity of Martinez, in Contra Costa County, as well as in other parts of California. At Martinez and other localities a commingling of Cretaceous and Tertiary types such as has already been referred to actually occurs, but in all cases the Tertiary types appear to increase toward the upper part of the series and the Cretaceous types toward the lower part. In other words, it appears that the base of the series has a preponderance of Cretaceous types and the upper part a preponderance of Tertiary.

The Eocene age of the Tejon was again mentioned by White[2] in announcing the occurrence of *Cardita planicosta* Lam. in Oregon, and the evidence of conformability and stratigraphic continuity of the Chico-Tejon series was presented by Becker[3] in 1885.

In subsequent publications White[4] has repeated essentially the same views. In the first of these he says:

There seems to be no longer any reason why one should hesitate to accept it as a demonstrated fact that we have in California a continuously deposited series of strata, the lower portion of which is characteristically Cretaceous and the upper portion of which is no less characteristically Eocene Tertiary, and that the Cretaceous characteristics gradually disappear upward, leaving the surviving fauna with its later accessions without any commingling of Mesozoic types.

Further on in the discussion of the fauna he adds:

Besides the numerous molluscan species of Tertiary types which Mr. Gabb described

[1] Bull. U. S. Geol. Survey No. 15, pp. 11–17.
[2] Bull. U. S. Geol. Survey No. 18, pp. 7–9.
[3] Bull. U. S. Geol. Survey No. 19.
[4] Bull. U. S. Geol. Survey No. 51, 1889, pp. 11-14. Bull. U. S. Geol. Survey No. 82, 1891, pp. 181-198.

and figured from the Chico-Tejon series in the two volumes of Palæontology of California, I may refer for present comparison to the following, among others, which are described and figured in this bulletin: *Fulgur hilgardi*, *Cominella lecontei*, and *Trophon condoni*. And yet I have broken these fossils out of the matrix in which they were embedded and wherein they were commingled with such Cretaceous types as *Ammonites chicoensis* Trask, *Baculites chicoensis* Trask, *Cinulia obliqua* Gabb, *Trigonia evansana* Meek, and *Inoceramus whitneyi* Gabb. Still, in the collections here particularly referred to, which come from well down in the Chico portion of the series,[1] the Tertiary types are somewhat more conspicuous as to numbers than the Cretaceous types.

Clark[2] has also given a careful review of the literature on the Tejon formation, which he regards as a representative of probably the entire Eocene. The continuity of life and deposition from the Cretaceous to the Eocene is accepted as proved.

Harris[3] has compared the Tejon fauna as developed near Fort Tejon with the fauna of the Lower Claiborne of the Gulf border, showing that a number of species are identical and others are closely similar. As the Claiborne is not the oldest Eocene of the Southern States, it was suggested that older Eocene faunas ought to be found in California. It should be remembered in this connection that the fossiliferous beds in the neighborhood of Fort Tejon probably represent the upper part of the Tejon formation in the Mount Diablo region.

Meanwhile the geologists of the United States Geological Survey, especially Messrs. Diller and Turner, had collected Tejon and Chico fossils from many localities in California, Oregon, and Washington, which were referred to the present writer for determination. The study of these collections from localities north of middle California showed no evidence of a gradual transition from one fauna to the other in that region, and Diller[4] reported that there is a decided unconformity between the Cretaceous and the Tejon in Oregon. The fauna of the basal beds of the Chico was shown to be closely connected with the older Horsetown fauna, and probably as old as the Cenomanian, and the suggestion was made that the latest Cretaceous is not represented in the Chico. In 1894 a joint paper was published by Diller and Stanton[5] in which the same views, slightly modified, were expressed after they had visited together the more important Cretaceous localities in the Sacramento Valley. The following quotation will show their views at that time:

It is a significant fact that the most abundant Ammonites of the Chico belong to the genus Schloenbachia (in the broad sense in which the name is used in Europe). *Ammonites chicoensis*, *A. tehamaensis*, and two undescribed species belong here, and these are all found in the upper beds of the Chico. In other American Cretaceous areas this genus does not pass above the top of the Colorado formation and its

[1] From localities on Little Cow Creek and near Pence's ranch, both on the east side of Sacramento Valley. It may be noted in passing that none of the "Tertiary types" mentioned have yet been found in the Tejon.

[2] Bull. U. S. Geol. Survey No. 83, Correlation Essays, Eocene, pp. 95-110.

[3] Science, Aug. 18, 1892, vol. 22, p. 97.

[4] See Diller in Bull. Geol. Soc. Am., vol. 4, 1893, pp. 218-220, and Stanton, ibid., p. 255.

[5] Bull. Geol. Soc. Am., vol. 5, pp. 435-464.

equivalents,[1] and in Europe it seems not to occur above the "Emscher Mergel," or lowest Senonian. *Ammonites turneri*, which was found near Mount Diablo associated with *Anchura californica* and other Lower Chico species, is an Acanthoceras closely related to European species that occur in the Cenomanian. The other Ammonites known from these beds do not resemble those characteristic of the latest Cretaceous. The two abundant species of *Trigonia*, *T. evansana*, and *T. leana* likewise have their nearest relative in the lower part of the Upper Cretaceous of Europe. * * *

In Oregon the Tejon appears to overlie unconformably the Shasta-Chico series under such conditions as to suggest that a considerable period of erosion occurred between the uplifting of that series and the deposition of the Tejon. The faunas of the Chico and the Tejon as developed there are entirely distinct. The stratigraphic and faunal evidence tends to show that in the region in which we have studied it the Chico does not represent the very latest Cretaceous time, perhaps not later than the close of the Colorado epoch, or the Turonian and earliest Senonian of Europe.

For the present, therefore, the Shasta-Chico series may be regarded as representing the whole of the Lower Cretaceous and the earlier half of the Upper Cretaceous, with the proviso that there may be still later Cretaceous beds in middle California, where the Chico and Tejon are said to be conformable and their faunas have been reported to contain a number of common species.

It is seen from a study of the literature that the evidence for the close faunal connection between the Chico and the Tejon depends almost entirely on Gabb's observations and collections in the Mount Diablo region, including Martinez, Benicia, and Clayton, and near Lower Lake, in Lake County. The verification of the evidence involves the study of the stratigraphy and the vertical range of the species at these localities and the determination of the limits of Gabb's Martinez group and "intermediate beds." It will also be necessary to characterize the Chico fauna briefly with special reference to the Tertiary types it is supposed to contain, and to describe some of the more important fossils from the Lower Tejon.

At the outset a serious difficulty is encountered owing to the fact that no stratigraphic or lithologic definitions of the various subdivisions were given in the publications of the California Geological Survey, nor were the localities at which fossils were collected usually described with sufficient definiteness and accuracy to enable one to identify them in the field. For example, the locality "Martinez" is given for a large number of species assigned to the Chico, the Martinez, and the Tejon groups and the intermediate beds, but it is evident from the distribution of the outcrops that these fossils must have been collected at many localities scattered over an area extending probably 4 or 5 miles south, southwest, and southeast of Martinez. The Clayton and Benicia localities likewise cover considerable areas in which several horizons are exposed.

The field observations embodied in the following notes were made during the summers of 1893 and 1894, part of the time independently and part of the time in the field parties of Messrs. H. W. Turner and

[1] A possible exception to this statement, not given in the paper quoted, is *Ammonites delawarensis* Morton, which in New Jersey and Texas occurs associated with a fauna that can hardly be referred to a horizon lower than the Fort Pierre.

J. S. Diller, to both of whom I am greatly indebted for material collected and assistance rendered. Dr. John C. Merriam, of the University of California, spent a few days with me in the vicinity of Clayton and Mount Diablo, and in subsequent correspondence he has communicated important facts obtained in the course of detailed field work in that region.

For free access to the collections and in some cases for the loan of important material, I am under great obligations to the officers in charge of the collections in the Academy of Natural Sciences, Philadelphia, the United States National Museum, the University of California, and especially the California State Mining Bureau.

LOCAL DEVELOPMENT AND STRATIGRAPHY.

MOUNT DIABLO REGION.

The area to be discussed under this title includes localities on Currys Creek, south of Mount Diablo, Clayton, and the coal mining villages a few miles north and northeast of the mountain, Pacheco and northwestward to Martinez, and Benicia, on the Strait of Carquinez. Mount Diablo itself is about 27 miles north of east from San Francisco. Clayton is near the north base of the mountain and 13 miles southeast of Martinez, with Pacheco on the road between the two places and about 6 miles from Martinez.

Notes on the geology of this region have been published by Blake and Newberry in the volumes of the Pacific Railroad Reports already cited. It has also been described by Whitney,[1] and more recently Turner[2] has given a more detailed description of the area immediately surrounding the mountain. His notes and collections from the neighborhood of Martinez and Benicia have also been placed at my disposal and have been freely used.

The unaltered sedimentary rocks, among which the Knoxville, Chico, Tejon, Miocene, and Pliocene are recognized, dip steeply away from Mount Diablo on all sides, but toward Martinez the general structure is that of a parallel series of anticlinal and synclinal folds with a northwesterly strike. The harder beds form ridges, sometimes of considerable height, but they are usually rounded and soil covered, with comparatively small rock exposures. The intervening valleys and many of the ridges themselves are cultivated fields, and no single section of any length across the strike shows more than a small proportion of the beds. There are some exceptions to this statement near the coal mines east of Clayton, where there are large exposures of Tejon sandstone, and in the bluff near the arsenal at Benicia, where a large part of the Chico and the Lower Tejon are fairly well exposed.

The Knoxville beds are recognized on the north side of Mount Diablo by the occurrence of *Aucella piochii* Gabb and a few other forms at

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[1] Geol. Surv. California Geology, Vol. I, pp. 11–32, 100–102.
[2] Bull. Geol. Soc. Am., vol. 2, 1891, pp. 383–414.

several points, but no fossils characteristic of the Upper Knoxville or of the Horsetown beds have been found in this region.[1] These horizons may be represented in the unfossiliferous beds of considerable thickness between the Aucella localities and the lowest known Chico fossils, though for our present discussion the question is not important. Fossiliferous strata occur in the Chico on Currys Creek (or Currys Cañada) south of Mount Diablo, where they have yielded—

Trigonia evansana Meek.
Caryatis nitida Gabb.
Mactra tenuissima Gabb.
Anchura californica Gabb.
Scobinella dilleri White.
Acanthoceras turneri (White).
Baculites chicoensis Trask.

The Acanthoceras and the Anchura indicate a rather low horizon in the Chico, the former being of a type that in Europe is regarded as characteristic of the Cenomanian.

On the north and east sides of the mountain the Cretaceous beds overlying the Aucella-bearing horizon were not found to be fossiliferous excepting near the top of the Chico exposed in the end of a hill one-half mile north of Clayton, where a few specimens of *Baculites chicoensis* and of undetermined species of Corbula and Nucula were collected. Another locality, about a mile northeast of Clayton and a short distance northwest of one of the abandoned coal mines (the old Peacock mine), yielded *Baculites chicoensis* and casts of a large species of Mactra. This is a somewhat higher horizon than the last-mentioned locality, and is the highest horizon of this neighborhood at which Chico fossils were found. It is not more than 400 feet beneath the Tejon coal beds, which have suffered some displacement, and the topography is such that at first sight one might think the coal beds are lower than the fossil horizon. This fact is suggestive when it is remembered that one of Gabb's localities for ammonites in the Tejon is in this immediate neighborhood.

The thickness of Cretaceous strata from the Aucella bed to the highest Chico fossils is estimated at not more than 5,000 feet in this section. The rocks are dark clays, interbedded with bands of sandstone that are brown on weathered surface and dark-bluish within. The sandstones become thicker and generally softer toward the top.

The contact between the Chico and the Tejon was not found exposed at any place near the coal mines east of Clayton, but it is evident that the coal beds are not far above the base of the Tejon. Gabb reports the occurrence of *Cucullæa matthewsoni* and *Fasciolaria leviuscula* in the "intermediate beds" beneath the coal near Clayton, thus indicating a horizon much better represented by fossils near Pacheco, Benicia, and Lower Lake. At Summersville, one of the coal-mining villages east of Clayton, an undescribed species of Corbicula occurs abundantly in a layer beneath the lower coal bed.

The beds associated with and immediately overlying the coal consist

[1]Gabb reports *Ammonities batesi* Trask, a characteristic Horsetown species, from the Chico at Benicia. I have not been able to find this specimen in any of the collections, but it was most probably not correctly identified.

mostly of light-colored, rather coarse, friable sandstone, 400 or 500 feet in thickness. In most of the exposures examined they are fossiliferous only in the upper part, where they contain a typical Tejon fauna like that described from Fort Tejon. Probably the lowest of these fossiliferous horizons above the coal is exposed in a low hill just west of Summersville and south of the cemetery, in sandstones not more than 100 feet above the principal coal bed mined there, and perhaps 300 feet above the base of the sandstones. The following species have been identified in the collection from this place:

Modiola ornata Gabb.	Pectunculus sagittatus Gabb.
Venericardia planicosta Lam.	Cardium cooperi Gabb.
Lucina gyrata (Gabb).	Solen parallelus Gabb.
Corbula parilis Gabb.	Meretrix uvasana Conrad?
Tellina hoffmanniana Gabb.	Corbula hornii Gabb.
Turritella uvasana Conrad.	Amauropsis alveata (Conrad).
Solarium cognatum (Gabb).	Rimella macilenta White.
Ficopsis remondi Gabb.	Fusus californicus Conrad.
Aturia matthewsoni Gabb?	

The Tejon strata, dipping strongly northward, may be traced almost continuously from Summersville west toward Clayton for 3 or 4 miles, and fossils evidently belonging to the same fauna with those named above are abundant at several places at horizons apparently all somewhat above that at Summersville and ranging through a thickness of several hundred feet. One of the most prolific of these localities is on a hill south of the Clayton-Summersville road and about 2½ miles N. 35° E. of Clayton, where the following species were obtained:

Leda gabbi (Conrad).	Fusus diaboli Gabb.
Nucula (Acila) truncata Gabb.	Perissolax blakei (Conrad).
Crassatella grandis Gabb.	Pleurotoma (Drillia) raricostata Gabb.
Crassatella uvasana Conrad.	Bela clathrata Gabb.
Tellina hoffmanniana Gabb.	Fusus occidentalis Gabb.
Meretrix uvasana Conrad.	Pleurotoma sp.
Lunatia nuciformis Gabb.	Ficopsis remondi Gabb.
Lunatia hornii Gabb.	Conus remondi Gabb.
Galerus excentricus Gabb.	Olivella matthewsoni Gabb.
Solarium cognatum (Gabb).	Cylichna costata Gabb.

At other localities a little farther west, where smaller collections were made, many of the same species were obtained, together with a few others, such as—

Venericardia planicosta Lam.	Dentalium stramineum Gabb.
Mysia polita Gabb.	Tritonium hornii Gabb.
Neæra dolabræformis Gabb.	Ficopsis hornii Gabb.
Gadus pusillus Gabb.	Megistostoma striata Gabb.

The fauna represented by these lists is clearly the original Tejon fauna that occurs in the neighborhood of Fort Tejon, New Idria, and elsewhere along the coast ranges to Washington. Its Eocene character has been recognized by Conrad, Marcou, Heilprin, White, and others. The Tejon beds above these fossiliferous zones have yielded no fossils in the coal-mining district east of Clayton, but the strata assigned to the Tejon, consisting of massive light-colored sandstones with thinner beds of clay, have an apparent thickness of at least 4,000 feet. They are overlain by fossiliferous Miocene beds, which seem to have the same dip, though the actual contact was not seen.

In the long ridges west of the road between Pacheco and Martinez the upper parts of the Tejon and the Miocene are again exposed, with a northwest strike and a steep dip to the southwest. A fossiliferous horizon in the Tejon here is apparently higher in the series than those near Clayton, as it is not more than 1,000 feet below the fossiliferous Miocene. At a point 1 mile northwest of Pacheco the following species were found in this upper horizon of the Tejon:

Pectunculus sagittatus Gabb.	Solen parallelus Gabb.
Nucula truncata Gabb?	Lucina gyrata (Gabb).
Cardium cooperi Gabb.	Turritella uvasana Conrad.
Meretrix uvasana Conrad?	

This locality is on or near the line of Gabb's diagrammatic "section from near Pacheco to the Cañada del Hambre,"[1] and is in the sandstones there marked *b'*. This section, which is 4 miles in length, has Chico strata at each end, with Tejon, Miocene, and Pliocene in regular succession toward the middle, thus showing synclinal structure, probably somewhat modified in places by faulting. The same structure is continued all the way to Martinez and Benicia. It is indicated at Martinez by the occurrence of the Chico on Bulls Head Point, east of the town, and in the hills on the west, with exposures of the Tejon between them.

There is another fossiliferous horizon in the Tejon several hundred feet below the one near Pacheco just mentioned. It is exposed in the ridge east of the road from Pacheco to Martinez, and was found to be most fossiliferous near the southern end of this ridge, 1 mile north of Pacheco, in the angle between the roads to Martinez and to the Pacheco warehouse.

The fossils from this locality were not all found in place, some of them being in stone heaps collected from the field; but they are evidently all from approximately the same horizon, since they are found in similar association elsewhere. Many of them were collected by Mr. H. W. Turner. The list of identified species is as follows:

Leda gabbi Conrad.	Lunatia sp.
Leda alæformis (Gabb).	Brachysphingus liratus Gabb.
Pectunculus sagittatus Gabb?	Nassa antiquata Gabb.
Venericardia planicosta Lam.	Heteroterma striata Stanton.
Tapes? quadrata Gabb.	Urosyca caudata Gabb.
Mactra sp.	Tritonium whitneyi Gabb?
Corbula parilis Gabb.	Mitra cretacea Gabb.
Dentalium cooperi Gabb.	Cancellaria turneri White.
Turritella infragranulata Gabb.	Strepsidura pachecoensis Stanton.
Turritella pachecoensis Stanton =T. Saffordi Gabb.	Siphonalia? lineata Stanton.
	Ampullina striata Gabb?
Lunatia nuciformis Gabb.	Cylichna costata Gabb.

[1] Geol. Surv. California, Geology, Vol. I, p. 14.

These fossils represent a well-defined faunal zone, which I refer to the basal portion of the Tejon. It occurs at Benicia and near Lower Lake, and the fossils described from it by Gabb were assigned in part to the Martinez group and in part to the Tejon and the "intermediate beds," which will be more fully discussed in connection with the Lower Lake localities.

The next fossiliferous horizon exposed north of Pacheco is some 1,200 or 1,500 feet lower, in bands of conglomerate forming low ridges and knolls, where the following species were obtained:

Meekia sella Gabb.
Pharella alta Gabb.
Tellina matthewsoni Gabb.
Lutraria truncata Gabb.
Perissolax brevirostris Gabb, variety.

The same horizon is exposed in the first range of hills west and southwest of Martinez, where it yields a greater variety of fossils, as follows:

Mytilus pauperculus Gabb.
Pectunculus veatchi (Gabb).
Meekia sella Gabb.
Meretrix arata Gabb.
Chione varians Gabb.
Tellina ooides Gabb.
Corbula cultriformis Gabb.
Solarium inornatum (Gabb).
Gyrodes expansa Gabb.
Gyrodes conradiana Gabb.
Pugnellus hamulus Gabb.
Perissolax brevirostris Gabb, variety.
Helicoceras? vermicularis Gabb.
Pachydiscus sp.

These fossils clearly belong to a Cretaceous fauna not distinguishable from the Chico, and they are all distinct from the species collected in the next higher fossiliferous bed, the Lower Tejon of the same region.

The strike of these Chico and Lower Tejon beds carries them across the Strait of Carquinez from Martinez to the neighborhood of Benicia and Army Point, where they are somewhat better exposed along the shore from Army Point station for a mile or more northeastward. The most fossiliferous horizon in the Cretaceous of this section is a conglomerate that crops out in bluffs near the shore a little over a mile northeast of the station. The fossils obtained were—

Cucullæa gravida (Gabb).
Pectunculus veatchi Gabb.
Trigonia leana Gabb.
Trigonia evansana Meek.
Turritella sp.
Rostellites gabbi (White).
Ammonites jugalis Gabb.

The overlying beds consist of brownish sandstones interbedded with clays, dipping steeply to the southwest, excepting at one point, where for a short distance the dip is reversed. They contain occasional Cretaceous fossils, such as *Inoceramus whitneyi*, *Meekia sella*, *Pharella alta*, and *Chione varians*, the last of these Cretaceous fossiliferous bands being near the principal arsenal building at Army Point. If there are no local folds or faults, the total thickness of beds containing Chico fossils in this section is not less than 3,000 feet.

Above the recognized Chico there are 1,200 or 1,500 feet of strata, consisting mainly of light-colored sandstones, in which no fossils were found, followed by similar fossiliferous sandstones exposed in a low bluff not more than 200 yards northwest of the railroad station at Army Point. Here the following species were collected:

Flabellum remondianum Gabb.	Pholadomya nasuta Gabb.
Cucullæa matthewsoni Gabb.	Turritella infragranulata Gabb.
Nucula sp.	Lunatia sp.
Crassatella sp.	Perissolax blakei (Conrad).
Tapes? quadrata Gabb.	Urosyca caudata Gabb.
Meretrix sp.	Ampullina striata Gabb.
Tellina? undulifera Gabb.	Actæon sp.
Mactra sp.	

Another exposure on the railroad between Army Point and Benicia, apparently several hundred feet higher in the section, yielded the following species belonging to the same fauna:

Modiola ornata Gabb.	Fusus flexuosus Gabb.
Pectunculus sagittatus Gabb?	Turritella infragranulata Gabb.
Nucula (Acila) truncata Gabb.	Brachysphingus liratus Gabb.
Meretrix sp.	Cylichna costata Gabb.
Tellina? undulifera Gabb.	Actæon sp.
Tellina hoffmanniana Gabb.	

The fossils from these two exposures are elsewhere closely associated, belonging to the fauna of the lower Tejon, and it is probable that there has been some folding or faulting that has caused a repetition of the same beds. It should be noted that this fauna contains no types that can be considered characteristically Cretaceous, while there are some, such as the coral Flabellum, that are not known in beds older than the Eocene. The species are different from those of the latest Cretaceous fossils of the same section, though here, as elsewhere, there is a considerable thickness of barren strata between.

LOWER LAKE AND THE INTERMEDIATE BEDS.

Another important locality is near the village of Lower Lake, in Lake County, about 75 miles north of San Francisco, where Gabb reported the discovery of intermediate beds which showed a commingling of the Chico and the Tejon faunas in a single thin stratum. His list of fossils from 1 mile southeast of Lower Lake is as follows:[1]

†*Avicula pellucida Gabb.	*Gyrodes expansa Gabb.
Lima multiradiata Gabb.	*Lunatia shumardiana Gabb.
*Axinæa veatchi Gabb.	†Galerus excentricus Gabb.
†*Cucullæa matthewsoni Gabb.	†Spirocrypta pileum Gabb.
†Crassatella grandis Gabb.	†Brachysphingus liratus Gabb.
†Tapes conradiana Gabb.	*Perissolax brevirostris Gabb.
Corbula alæformis Gabb.	†Fusus californicus Gabb.
*Turritella saffordi Gabb.	†Fasciolaria læviuscula Gabb.
†*Amauropsis alveata (Conrad).	

Considerable collections were made by me from the original locality

[1] The species marked thus * were reported to occur in the Chico, and those marked † in the Tejon. Some of the supposed Chico species do not really occur in that formation, and it is almost certain that several of the identifications were incorrect.

on Herndon Creek, and also from material taken from a well at an old brickyard one-fourth mile nearer town, but on the same horizon. The following species were obtained:

Flabellum remondianum Gabb? Fragment.
Terebratulina tejonensis Stanton.
Plicatula ostreiformis Stanton.
Lima multiradiata Gabb.
Perna sp.
Modiola ornata Gabb.
Cucullæa matthewsoni Gabb.
Pectunculus veatchi, var. major Stanton.
Leda gabbi Conrad.
Leda alæformis (Gabb) = Corbula alæformis.
Crassatella unioides Stanton.
Venericardia planicosta Lam.
Lucina turneri Stanton.
Meretrix sp.
Tellina hornii Gabb?
Tellina æqualis Gabb.
Tellina hoffmanniana Gabb.
Solen parallelus Gabb.
Dentalium cooperi Gabb.
Patella sp.
Turritella pachecoensis Stanton = T. saffordi Gabb.
Turritella martinezensis Gabb.
Turritella infragranulata Gabb.
Lunatia hornii Gabb.
Ampullina striata Gabb.
Galerus excentricus Gabb.
Cerithiopsis alternata Gabb.
Brachysphingus liratus Gabb.
Urosyca caudata Gabb.
Heteroterma gabbi Stanton.
Heteroterma striata Stanton.
Siphonalia ? lineata Stanton.
Cypræa bayerquei Gabb.
Actæon sp.
Cylichna costata Gabb?

While this list contains several species that have not been found elsewhere, it also contains a large proportion of the most characteristic forms of the Lower Tejon at Benicia (Army Point) and near Pacheco, so that there can be no doubt that practically the same horizon is represented at all three places. Chico species, with the exception of forms that appear to be specifically identical with *Pectunculus veatchi* and *Tellina hoffmanniana*, are absent. One of the forms which I have referred to Heteroterma was probably identified by Gabb as *Perissolax brevirostris*, and his *Gyrodes expansa* was probably also an erroneous identification.

The paleontological evidence, therefore, warrants the reference of the "intermediate beds" to the lower part of the Tejon as it is developed in the Mount Diablo region, where some localities of the same zone must have been included in Gabb's Martinez group.

Owing to the absence of other recognizable horizons, the stratigraphy of the Lower Lake region adds little to our knowledge of the position of the zone. The fossils enumerated above occur not more than 300 or 400 feet north of the southern edge of a belt about 2 miles wide, consisting largely of light-colored sandstones with some beds of clay and bands of conglomerate. The strike is nearly east and west, and the dip is very high, often vertical. South of this sandstone there are heavy beds of crumpled clay-shales with thin sandstones and occasional calcareous lenses. These are doubtless of Cretaceous age, but in the absence of fossils their exact horizon could not be determined. Precisely similar beds occur on the north side of the sandstone belt at a locality on the north side of Cache Creek about 2½ miles northwest of

Lower Lake, and some 400 feet within the sandstone belt a number of the Lower Tejon species were found, including—

Ostrea appressa Gabb.
Perna sp.
Leda alæformis (Gabb).
Meretrix sp.
Tellina sp.
Dentalium cooperi Gabb.
Turritella pachecoensis Stanton.
Natica sp.
Ancillaria sp.

This locality is about 2 miles across the strike from the localities that yielded the larger collection from the same horizon. It is evident that we have here a closely folded syncline, the rocks between the two localities of Lower Tejon probably having a thickness of 3,000 or 4,000 feet. The few fossils that have been found in the intervening beds include an Ostrea, a Natica, and *Crassatella uvasana* Conrad, the latter being an Upper Tejon species. Possibly there are later beds in the middle of the fold, but it is more probable that the entire thickness belongs to the Tejon.

NEW IDRIA.

This locality, 150 miles southeast of San Francisco, has been mentioned by White[1] as affording the most satisfactory evidence of the close stratigraphic connection between the Chico and the Tejon, and the general geology of the region has been fully described in Becker's Geology of the Quicksilver Deposits of the Pacific Coast.[2] The Chico and Tejon beds have been described more in detail by Turner,[3] with lists of fossils from the Tejon determined by Stanton. Collections were also made here by the State Geological Survey, and several Tejon species from New Idria are mentioned by Gabb in the Palæontology of California. The Chico and Tejon are described as consisting almost entirely of sandstones in an apparently conformable series not less than 10,000 feet thick. The upper portion, which is referred to the Tejon, is lighter colored than the lower or Chico portion. The latter is generally unfossiliferous, having yielded only a few fragmentary specimens of Ammonites, Baculites, Trigonia, etc., sufficient, however, to prove its Cretaceous age, though there is a long interval between the last of these fossils and the lowest Eocene species, which occur near the base of the beds mapped as Tejon. This lowest fossiliferous zone in the Tejon of New Idria is well developed in De Los Reyes Canyon, occurring a few feet below the base of the lowest horizon of white sandstone cliffs in the section. The collections made there and at other localities on the same horizon in the neighborhood by Mr. Turner, and subsequently by myself, contain the following species:

Cristellaria sp.
Modiola ornata Gabb.
Cardium cooperi Gabb.
Ostrea idriaensis Gabb.
Pectunculus sagittatus Gabb.
Cardium breweri Gabb.

[1] Bull. U. S. Geol. Survey No. 15, p. 13.
[2] Mon. U. S. Geol. Survey, Vol. XIII, pp. 294–300.
[3] Am. Geologist, Vol. XIV, pp. 92–96.

Meretrix uvasana Conrad.
Tellina remondi Gabb.
Mactra sp.
Amauropsis alveata (Conrad).
Turritella uvasana Conrad.
Ficopsis remondi Gabb.
Morio (Sconsia) tuberculatus Gabb.
Cylichna costata Gabb.
Tapes conradiana Gabb.
Tellina hornii Gabb?
Dentalium cooperi Gabb.
Neverita globosa Gabb.
Rimella macilenta White.[1]
Conus remondi Gabb.
Fasciolaria? io Gabb.

Another horizon, some 500 feet higher, yielded:

Ostrea idriaensis Gabb.
Arca sp.
Tapes conradiana Gabb.
Corbula hornii Gabb.
Nerita (Theliostyla) triangulata Gabb.
Modiola ornata Gabb.
Venericardia planicosta Lam.
Solen parallelus Gabb.
Galerus excentricus Gabb.

Between these two horizons some shaly beds, associated with lignitic bands and apparently of brackish-water origin, contain great numbers of *Potamides carbonicola* Cooper and *Corbicula* sp. Near the top of the Tejon of this region, and probably included in it, are shales with *Mysia? polita* Gabb and *Pecten interradiatus* Gabb.

The Tejon fauna of this region contains no Mesozoic elements, and it seems to belong entirely to the Upper Tejon of the Mount Diablo region, though it is very probable that the basal Tejon beds are represented in the unfossiliferous strata of New Idria.

FORT TEJON.

The fossils from the country about Tejon described by Conrad and Gabb and those collected by Turner and Becker also indicate the same Upper Tejon horizons as at New Idria. Gabb lists more than 80 species from Fort Tejon, but nearly all of the characteristic species found in the Lower Tejon at Lower Lake, Benicia, and near Pacheco are absent. According to the descriptions of the region given by Blake[2] and Whitney,[3] there seem to be no Chico or older Cretaceous beds in the section, the Tejon resting directly on metamorphic and crystalline rocks.

SAN DIEGO AND OTHER LOCALITIES IN SOUTHERN CALIFORNIA.

Both Chico and Tejon rocks are exposed on the coast near San Diego, and species characteristic of both formations were described from there by Gabb. Fairbanks[4] has described the field relations of the beds, and has given partial lists of the fossils identified by Cooper, who has since published[5] fuller lists and described some new species. Valuable collections of fossils and notes illustrated by maps have also been sent to Dr. W. H. Dall by Mr. Homer Hamline, of San Diego, and these

[1] The types of this species which were collected here were inadvertently referred to the Chico. (Bull. U. S. Geol. Survey No. 51, p. 20.) It may be identical with *R. canalifera* Gabb.

[2] Pacific Railroad Reports, Vol. V, Part II, pp. 46–50, 163, 197–211.

[3] Geol. Surv. California, Geology, Vol. 1, pp. 186–197.

[4] Am. Jour. Sci., 3d series, Vol. XLV, June, 1893, pp. 473–478, and Eleventh Rept. California State Mineralogist. 1893, pp. 94–98.

[5] Bull. California State Mining Bureau No. 4, pp. 37–51, 60–63.

have been studied by me. Through the courtesy of the State mineralogist, Mr. J. J. Crawford, and other officials of the California Mining Bureau, I have been permitted to study Fairbanks's San Diego collections, and also the fossils listed by Watts[1] from Coalinga, the California and San Joaquin coal mines. The published lists from all these localities indicate some mixing of Chico and Tejon species, but on careful examination of the fossils it is found that all the Cretaceous species cited from Tejon localities, such as the coal mines mentioned, were wrongly identified.

The locality at the west base of Point Loma, near San Diego, yielded a characteristic Chico fauna, but, omitting erroneous identifications, there are with it a few forms, such as *Cylichna costata*, *Solen diegoensis* (?), and *Tapes quadrata* (?), that seem to belong to the Tejon. Besides these there are *Pectunculus veatchi* var. *major* and *Crassatella lomana*, closely related to *C. unioides*, both of which suggest the basal Tejon beds of Lower Lake. It should be noted, however, that part of Fairbanks's collection was obtained from bowlders, and although he was confident that the bowlders were derived from the beds that he found in place, it is possible that one or more of them may have been more recent. Hamline's collections do not show any blending of Chico and Tejon faunas. It is believed, therefore, that the collections from southern California can not be accepted as evidence of intimate faunal connection between the Tejon and the Chico.

OTHER TEJON AREAS.

The most southerly point on the Pacific Coast at which Tejon and Chico strata are known to occur is in Lower California (about latitude 29° 30′), where Emmons[2] obtained a few fossils belonging to each formation.

The Tejon is known to occur at many localities in western Oregon and as far north as the vicinity of Seattle, Wash. Diller's collections from these regions show a considerable fauna apparently belonging to the Upper Tejon. It contains no Cretaceous elements, and from the absence of most of the Lower Tejon characteristic forms it is inferred that the earliest Tejon is not represented there. The unconformability of the Tejon with the Cretaceous in Oregon, as described by Diller, has already been mentioned.

THE MARTINEZ GROUP AND ITS FAUNA.

As the Martinez group was not described nor definitely located in any section, it can be identified only by means of the fossils that were assigned to it. In Gabb's Synopsis of the Cretaceous Invertebrate Fossils of California[3] four localities are mentioned as yielding species belonging to the Martinez group, viz: Benicia; Curry's, south of Mount Diablo; Martinez; and near Suisun.

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[1] In Bull. California State Mining Bureau No. 3.
[2] Bull. Geol. Soc. Am., Vol. V, pp. 501-502.
[3] Palæontology of California, Vol. II, pp. 209-254.

From Benicia only four species are reported—

Ammonites jugalis Gabb.
Ammonites fraternus Gabb.
Cymbophora ashburneri Gabb.
Chione varians Gabb.

all of which are Cretaceous species and doubtless came from strata that I refer to the Chico.

The following species from Curry's are referred to the Martinez:

Ammonites jugalis Gabb.
Fusus matthewsoni Gabb.
Helicaulax costata Gabb.

The Fusus is a Tejon species which I collected on Curry's Creek from bowlders containing other Eocene fossils, and Gabb's specimens may have been found in a similar situation. The two other species probably came from the Chico beds of that neighborhood.

From the Suisun locality only two species are reported, one of which, *Turritella saffordi* Gabb (= *T. pachecoensis*), is a Lower Tejon species, while the type of the other, *Meretrix fragilis*, is from Martinez, where it is said to be associated with *Pugnellus hamulus* and *Meekia sella*, both of which are Cretaceous forms.

About fifty species assigned to this group are enumerated from the locality of Martinez, which includes a considerable area south, southeast, and southwest of the town, as has already been mentioned. In the following list, compiled from Gabb's Synopsis, the species that are now known to be Cretaceous are marked *, those that are known to be Tejon are marked †, and others are left unmarked or their probable horizon is indicated by a query following the asterisk or dagger:

Astrocoenia petrosa Gabb.
Pecten martinezensis Gabb.
† * Avicula pellucida Gabb.
* Mytilus pauperculus Gabb.
† Cucullæa matthewsoni Gabb.
† * Pectunculus veatchi (Gabb).
* † (?) Nucula (Acila) truncata Gabb.
† Leda gabbi (Conrad).
† (?) Crassatella compacta Gabb.
† (?) Cardita veneriformis Gabb.
* (?) Lucina nasuta Gabb.
* Chione varians Gabb.
Chione ? angulata Gabb.
† Tellina ? undulifera Gabb.
† Tellina æqualis Gabb.
* † Tellina hoffmanniana Gabb.
Solen (Hypogella) cuneatus Gabb.
* Pharella alta Gabb.
† Pholadomya nasuta Gabb.
* † (?) Martesia clausa Gabb.
Mactra? tenuissima Gabb.
* Mactra (Cymbophora) ashburneri Gabb.
Corbula cultriformis Gabb.
† * Dentalium cooperi Gabb.
Helcion ? circularis Gabb.
† Turritella infragranulata Gabb.
† Turritella saffordi Gabb (= T. pachecoensis).
† * (?) Lunatia shumardiana Gabb.
* Gyrodes expansa Gabb.
† * (?) Amauropsis alveata Gabb.
† Ampullina striata Gabb.
* Solarium inornatum (Gabb).
* Anchura exilis Gabb.
* Anchura transversa Gabb.
* (?) Anchura ? carinifera Gabb.
* Pugnellus hamulus Gabb.
† Fusus matthewsoni Gabb.
† Fusus flexuosus Gabb.
† (?) Fusus tumidus Gabb.
† (?) Fusus occidentalis Gabb.
Neptunea mucronata Gabb.
* Perissolax brevirostris Gabb.
† Urosyca caudata Gabb.
Ataphrus crassus Gabb.
Turbinella crassitesta Gabb.
† (?) Surcula inconspicua Gabb.
† (?) Heteroterma trochoidea Gabb.
* (?) Ringinella pinguis Gabb.
† (?) Cylindrites brevis Gabb.
† * (??) Cylichna costata Gabb.
† Aturia matthewsoni Gabb.
* † (?) Ammonites jugalis Gabb.

If this list is analyzed in the light of the knowledge derived from later collections and stratigraphic observations, it becomes evident that it consists of about equal numbers of species from two distinct horizons. One of these is the Upper Chico, as developed near Benicia, 1 mile north of Pacheco, and in the hills west of Martinez. The other is the Lower Tejon horizon, which Gabb sometimes called "intermediate beds," and which has yielded many fossils at the localities near Lower Lake, Benicia, and Pacheco. Still further confusion was caused by the fact that in some cases species that really occur together were described as coming from different horizons; that is, some of the Lower Tejon species were described as Chico, others from the same horizon as Tejon, while the most of them were referred to the Martinez.

When the line between the Chico and Tejon is drawn where I have placed it, within the Martinez group of Gabb, the commingling of Cretaceous and Tertiary types almost entirely disappears.

The Martinez group as characterized by the fossils assigned to it by Gabb can not be treated as a single formation nor as a mere subdivision of the Chico. If more detailed field work makes it desirable to retain the name at all, it should be restricted to the Eocene portion, which is called Lower Tejon in this paper.

NOTES ON SPECIES REPORTED FROM BOTH CHICO AND TEJON.

Gabb could list but 16 species that passed from the Chico to the Tejon, and a critical examination of the list will show that certainly not more that 6 of these cross the line as now drawn between the two formations.

The statements concerning localities in the following list, unless otherwise noted, are from Palæontology of California, Vols. I and II:

1. Callianassa stimpsoni Gabb.

Represented by three fragmentary specimens from Chico Creek, Clayton, and Cañada de las Uvas, so imperfect that it is impossible to determine whether they all belong to one species or not.

2. Nautilus texanus Shumard?

Heilprin has called attention to the confusion of a specimen "collected by Mr. Clayton" with the locality Clayton, which caused Gabb to cite this species from the Tejon. The specimens are from Cottonwood Creek, Alderson Gulch (both Lower Cretaceous), and near Mount Diablo.

3. Aturia matthewsoni Gabb.

Vol. I, p. 59, "Martinez and Clayton (Division A) and Cañada de las Uvas (Division B)."

Vol. II, p. 210, "Martinez Group, Martinez; Tejon Group, Clayton and Tejon." These probably all came from the Tejon.

4. AMMONITES JUGALIS Gabb.

The localities and horizons given for this species (Vol. II, p. 212) are: "Martinez group, Martinez; Benicia, Curry's, south of Mount Diablo; Tejon group, Martinez and Clayton." Specimens afterward referred to it were described and figured as the young of *Ammonites newberryanus*. Concerning its occurrence, Gabb says (Vol. II, p. 134): "I have collected it in the latter [Tejon group] in place at the very top of the series at the coal mines near Clayton. Pl. 10, figs. 5 and 6*b*, Cal. Report Pal., Vol. I, are from a specimen from above the coal beds on Coal Mine Hill, near Mount Diablo." In another place (Am. Jour. Conchol., Vol. II, p. 89) he says: "Several specimens were collected by myself associated in the same rock and within a few feet of a specimen of *Cardita hornii*" [= *Venericardia planicosta*]. These statements would indicate that all the specimens of Ammonites found in the Tejon probably came from the upper part of that formation, though it has already been suggested on a previous page that there may possibly have been an error in determining the horizon of the Clayton specimen. The fragment of an undetermined ammonoid found by Heilprin in the collections from Fort Tejon at the Academy of Natural Sciences, Philadelphia, also seems to have come from an Upper Tejon horizon. Unfortunately, this specimen has been lost or mislaid, and can not now be found in the Academy's collections.

The specimens referred by Gabb to *Ammonites jugalis* apparently include 2 species, differing especially in the convexity of the whorls and in the details of the septa. At the University of California, Berkeley, there are 8 small specimens of the flat variety, including the one "from Coal Mine Hill, near Mount Diablo," figured in Palæontology of California, Vol. I, pl. 10, fig. 5. The others are labeled "Martinez" and "Mount Diablo." In the Philadelphia Academy collections there are 16 specimens, all in one tray with two labels—"*Ammonites jugalis* Gabb, type, Chico Gr., W. M. G., Benicia, Martinez, Cal.," and "*Ammonites jugalis* Gabb, W. M. G., Martinez Gr., Martinez Cal." This lot includes the specimens figured in Palæontology of California, Vol. II, pl. 22, figs. 13, 13*a*. The other figured specimen, which appears to me to belong to a distinct species, has not been seen by me in either of these collections.

Ammonites jugalis is apparently congeneric with *Desmoceras larteti* Seunes, from the uppermost Cretaceous of France, which de Grossouvre refers to his recently described genus Schlüteria. Ammonites that appear to be identical with Gabb's species occur in the lower part of the Chico, on Elder Creek, Tehama County, and on the north fork of Cottonwood Creek, Shasta County, Cal. It was also found in the lowest fossiliferous horizon of the Chico near Benicia.

No ammonoids have been found in any collections from the Tejon made since Gabb's time.

5. FUSUS MATTHEWSONI Gabb.

Reported from Martinez group at Martinez and Curry's; Tejon group at Martinez, Clayton, and Cochrane's.

It has been collected from Tejon bowlders near Curry's by Dr. J. C. Merriam and myself, and I suspect that it does not occur in place below the Tejon.

6. AMAUROPSIS ALVEATA (Conrad).

The only Chico locality mentioned is Curry's, where, like *Fusus matthewsoni*, it may have been collected from Tejon bowlders.

7 and 8. DENTALIUM STRAMINEUM Gabb. DENTALIUM COOPERI Gabb.

All that can be said of these two species is that striated and smooth species of Dentalium occur in both the Chico and the Tejon, and that there is no essential difference between Cretaceous and Tertiary forms of this genus.

9. CYLICHNA COSTATA Gabb.

Reported from the Chico group at Texas Flat, Pence's, and Martinez; Martinez group at Martinez; Tejon group at Martinez, Clayton, Cochrane's, Tejon, and San Diego.

In the original collection the specimens from different localities were not kept separate. All typical examples of the species obtained in recent years are from the Tejon, unless those in the Fairbanks collection from Point Loma, near San Diego, really came from the Chico. It belongs to a persistent type, however, that has showed little differentiation since its introduction in the Trias, and it would not be surprising to find identical species in the Upper Cretaceous and the Eocene.

10. MACTRA (CYMBOPHORA) ASHBURNERI Gabb.

Apparently two species were described under this name, both of which occur in the Chico. I have not seen a specimen that certainly belonged to either of them from any Tejon locality, though it is well known that Upper Cretaceous Mactras are of a modern type.

11. AVICULA PELLUCIDA Gabb.

The species, which was described from imperfect specimens, was reported from a number of localities in the Chico, Martinez, and Tejon groups. It belongs to a simple type of Avicula that is well represented in the Cretaceous and on to the present day.

12. CUCULLÆA MATTHEWSONI Gabb.

Credited to the intermediate beds at Lower Lake and Clayton and the Martinez group at Martinez.

The species seems to be confined to the Lower Tejon.

13. Nucula (Acila) truncata Gabb.

The types are from the Chico, where the species is abundant, but closely similar and probably identical forms are common throughout the Tejon. The subgenus Acila is a remarkably persistent type, represented by similar species from the Gault (*Nucula ornatissima* d'Orb. and *N. bivirgata* Fitton) to the present day (*N. castrensis* Hinds). Fairbanks[1] reports an Acila from beds at Slates Springs, Cal., said to be older than the Knoxville beds, and consequently as early as the Jurassic or lowest Cretaceous.

14. Leda gabbi (Conrad)=Leda protexta? Gabb.

As the only lower horizon mentioned is the Martinez group at Martinez, it is probable that all of Gabb's California specimens came from the Tejon, though similar species are known from the Upper Cretaceous elsewhere, and some living species are closely related.

15. Martesia clausa Gabb.

Reported from several Chico and Tejon localities. This genus is another persistent type that has varied but little from its first introduction to the present day.

16. Tellina hoffmanniana Gabb.

This is described as a variable species and reported from many localities in both Chico and Tejon. The specimens I have seen are mere internal casts with about the same outline. Many of the Upper Cretaceous species of Tellina are of modern type, scarcely distinguishable from recent forms.

From the intermediate beds at Lower Lake, which have been shown to be Tejon, Gabb reported 3 other Chico species—*Perissolax brevirostris* Gabb, *Gyrodes expansa* Gabb, and *Pectunculus veatchi* (Gabb). The first of these was very probably a young specimen of *Heteroterma gabbi*, which, if not well preserved, might easily be mistaken for *Perissolax brevirostris*. The *Gyrodes expansa* was also probably an erroneous identification of some other naticoid form. The *Pectunculus* is not more than a fairly well marked variety of *P. veatchi*, which is another modern type represented by similar forms from the Cretaceous to the present day.

These notes are sufficient to show that, excepting the meager evidence of the occurrence of Ammonites in the Tejon, it can not be claimed that the fauna of any part of the Tejon contains important Mesozoic elements.

THE CHICO FAUNA.

The statements of several writers already referred to concerning the occurrence of Tertiary types in the Chico fauna make it necessary to

[1] In an unpublished paper read before the Geological Society of Washington. It was determined by Dr. John C. Merriam.

examine that fauna briefly. An indication of the nature of the fauna may be found in the notes on the Mount Diablo region given on a previous page, but it is best developed at a number of localities on the east side of Sacramento Valley, where the Chico beds were first discovered and named and where the supposed Tertiary elements of the fauna were observed. The most of the species now known have been described by Gabb,[1] White,[2] and Whiteaves.[3] The lowest beds of the Chico occur with abundant fossils on the west side of Sacramento Valley in Shasta and Tehama counties, Cal., where they have been described with faunal lists by Diller and Stanton,[4] and in Rogue River Valley, Oregon, where they have yielded the interesting fauna listed and discussed by Anderson.[5] The beds at the last-mentioned locality may include the uppermost strata of the Horsetown beds, which in California are immediately succeeded by the Chico without faunal or stratigraphic break.

That the Chico fauna as a whole is Upper Cretaceous will not be questioned by anyone who has studied it in its entirety or who has even examined a representative collection from a single locality. Although some species do not range throughout the entire formation, no definite faunal zones can be established with our present knowledge, and it is doubtful whether it will ever be found necessary or practicable from paleontological evidence to subdivide the 4,000 feet or more of Chico beds. The close relationship of the lowest Chico with the Horsetown and the occurrence in it of such types as *Acanthoceras turneri* White and of an Inoceramus that seems to be identical with *I. labiatus*[6] Schlotheim indicate that the Chico includes beds almost as old as the earliest Upper Cretaceous of Europe.

On account of the occurrence throughout the Chico of Schloenbachia and of some other forms which are not found in the uppermost Cretaceous elsewhere in the United States, it was suggested in a previous paper[7] that the Chico may not include beds representing the latest Cretaceous of other parts of the world. It is not certain that that suggestion was incorrect, but the affinities of our west coast Cretaceous faunas are much closer with those found on the opposite side of the Pacific, in southern India, Japan, and Saghalien, than with other Cretaceous faunas in the United States, and the ammonitic types above mentioned range up into beds in India that are regarded as very late Cretaceous by European paleontologists.[8] Among other characteristic

[1] Palæontology of California, Vols. I and II. The synopsis in Vol. II designates the Chico species.

[2] Bull. U. S. Geol. Survey Nos. 22 and 51. The species in Bulletin 22 are from the Waliala beds, now known to be Lower Chico.

[3] Geol. Surv. Canada, Mesozoic Fossils, Part II. These are from the Nanaimo formation of Vancouver Island, which is correlated with the Chico.

[4] Bull. Geol. Soc. Am., Vol. V, pp. 438–445.

[5] Jour. of Geology, Vol. III, pp. 455–468.

[6] Reported by Anderson from the Oregon locality above mentioned and collected by Ward and Storrs in 1895 on Elder Creek, California.

[7] Bull. Geol. Soc. Am., Vol. V. pp. 460–461.

[8] The intimate relations of all the Cretaceous faunas around the borders of the Indo-Pacific basin are discussed, with full reference to the literature, by Dr. Franz Kossmat in Jahrbuch K.-k. geol. Reichsanstalt, Wien, vol. 44, 1894, pp. 459–478.

Cretaceous types that range through the Chico, may be mentioned ammonoids, such as 2 or 3 species of Lytoceras belonging to the group for which de Grossouvre has proposed the name Gaudryceras; several species of Pachydiscus, and 1 each of Scaphites, Baculites, and Heteroceras; 2 or 3 species of Inoceramus, Trigonia, and Meekia; several species of Anchura, Aporrhais, Pugnellus, Gyrodes, Rostellites, etc.

With these distinctively Mesozoic types in the littoral beds of the Chico, there are associated many other species belonging or closely related to genera now living. These are the species that have been spoken of as Tertiary types in the Chico, but the proportion of such forms is certainly not greater in the Chico than in the Ripley fauna of Alabama and Mississippi or in the Upper Cretaceous of Aachen, described by Holzapfel.[1] It would be more accurate to speak of such species as modern types or persistent types, for many of the living molluscan genera date back to the Cretaceous. Some of them, of course, began much earlier, but it is not until the Upper Cretaceous, and especially in the shallow-water facies of the Upper Cretaceous, such as the Chico usually is, that a considerable proportion of the invertebrate fossils can be referred to living genera. To mention only a few examples, in the Cretaceous there are species of Ostrea, Avicula, Mytilus, Modiola, Pectunculus, Lucina, Tellina, Mactra, Turritella, Lunatia, Neritina, Actaeon, Cylichna, Dentalium, etc., which, if taken alone, without knowledge of the specific forms or of the localities from which they came, would not furnish the basis for determining whether they are Cretaceous or later. In deciding a question of that kind, a species belonging to a long-established modern type should have very little weight.

RÉSUMÉ OF CONCLUSIONS.

1. In all known sections that contain both Chico and Tejon the strata are apparently conformable. So far as it goes, this is an indication of continuous sedimentation, but without further evidence it can not be accepted as proof that there is no break, nor should it be given greater weight than the clear unconformability between Tejon and older Cretaceous beds in Oregon.

2. The Martinez group of the California Survey is not a simple formation that can be considered a mere subdivision of the Chico, but consists of two distinct portions, one of which is Cretaceous and inseparable from the Chico, while the other is Eocene, and is here classed as Lower Tejon.

4. The "intermediate beds" supposed by Gabb to form a transition from the Chico to the Tejon are the same as the upper part of the Martinez group and the Lower Tejon. Their fauna, so far as known, includes no distinctively Mesozoic elements.

5. The Chico fauna is characteristically Cretaceous, its so-called "Tertiary types" being persistent or modern types that have changed but little from the Cretaceous to the present day.

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[1] Palæontographica, Vols. XXXIV and XXXV.

6. An examination of the species supposed to occur in both the Chico and the Tejon reduces their number to not more than 6, and with one exception those are all persistent types that can not be classed as Mesozoic. The exception is *Ammonites jugalis*, which Gabb collected from two localities supposed to be Tejon in the Mount Diablo region, but it has not been rediscovered in any subsequent Tejon collections. The ammonoid seen by Heilprin in the Gabb collection from Fort Tejon may or may not be this species. It is held that the Tejon fauna is essentially Eocene and very distinct from the Chico, even though this ammonite should prove to belong to it.

7. The time interval indicated by the decided change in faunas from the Chico to the Tejon can not now be estimated. In fact, there is little evidence that the later fauna is directly derived from the earlier excepting in a few species, and it is possible that all the changes took place by extinction and migration of species during the period in which the barren beds between the latest Chico and the earliest Tejon fossiliferous horizons were laid down. It will not be surprising, however, if evidence is some time found of a period of erosion at the close of the Cretaceous on the Pacific Coast.

DESCRIPTIONS OF SOME LOWER TEJON SPECIES.

As the fauna of the Upper Tejon is comparatively well known and its Eocene character generally recognized, it is not considered necessary to redescribe and illustrate it. In the Lower Tejon, however, there are some forms that have been confused with Chico species, some that are distinctly Eocene types, such as the coral *Flabellum remondianum*, others that have been imperfectly described, and a considerable number that seem to be new. Some of these important forms are now described and illustrated for the purpose of giving a more definite idea of the character of the Lower Tejon fauna.

Genus FLABELLUM Lesson.

FLABELLUM REMONDIANUM Gabb.

Pl. LXIII, figs. 1 and 2.

Flabellum remondianum Gabb, 1864, Geol. Surv. California, Paleontology, vol. 1, p. 207, pl. 26, fig. 199.

The following description of this species is by Mr. T. Wayland Vaughan, who has kindly allowed me to extract it from his manuscript monograph of the Eocene corals of the United States:

"The following is Gabb's description:

"'Polypidom triangular, convex on the sides, acute and straight on the lateral margins; sides marked by eight or nine prominent radiating ribs, with regularly concave interspaces; upper surface unknown.

"'*Locality.*—Between Mount Diablo and the Coal Mine.'

"Mr. T. W. Stanton collected near Benicia, Cal., many casts and specimens of this species embedded in sandstone. From the study of this material the following description has been made:

"Form cuneate, triangular, and compressed; the cross section shows acute, aliform projections at the ends of the longer transverse axis. On the sides in the upper portion of the corallum there are nine subacute prominent costæ, along the crests of which there are usually minute tubercles; in the lower portion of the corallum the costæ are very indistinct. Occasionally between the prominent costæ are fainter ones. The septa, in a section of a corallum that was studied, are thin, 78 (or 81) in number. There are only 22 of the fourth cycle, it being incomplete between one septum of the first cycle and the septum of the second cycle which corresponds to the middle of one lateral face. There are 32 septa of the fifth cycle, intercalated in the systems between the primary septa at the ends of the longer transverse and the primaries standing nearest the middle of the lateral faces. Apparently there are a few members of the sixth cycle in two of the systems next the termini of the longer transverse axis. The sides of the septa are granulate. Lower portion of corallum entirely filled by stereoplasm. Columella parietal.

"Dimensions: Longer transverse axis of an average specimen, 22 mm.; shorter transverse axis, 8 mm.

"Height of a smaller specimen: 11 mm.

"Locality: Army Point, near Benicia, Cal.

"Horizon: Lower Tejon beds.

"Specimens in the United States National Museum.

"The character of the costæ and the aliform projections are the best criteria by which to separate this species from the triangular varieties of *F. cuneiforme*, to which it is closely related."

Genus TEREBRATULINA d'Orbigny.

TEREBRATULINA TEJONENSIS n. sp.

Pl. LXIII, figs. 3 and 4.

Shell of medium size, elongate ovate in outline, moderately convex, with an obscure median depression in the ventral valve, which is rather narrow in the umbonal region and regularly rounded in front; dorsal valve relatively broader and more oval in outline; surface marked by small but rather prominent radiating striæ, most of which branch dichotomously twice in passing from the beak to the front. Most specimens also show several distinct lines of growth between the middle and the front of the valve.

The species is represented by a number of more or less distorted single valves, the largest of which, a dorsal (?) valve, measures 20 mm. in length and 16 mm. in greatest breadth. The other figured specimen is a more slender ventral valve, slightly distorted by pressure, measuring 18 mm. in length and 12 mm. in breadth.

Locality and position.—From the Lower Tejon beds 1 mile southeast of Lower Lake, Lake County, Cal., where it is associated with *Brachysphingus liratus, Urosyca caudata, Cucullæa matthewsoni*, etc.

Genus PLICATULA Lamarck.

PLICATULA OSTREIFORMIS n. sp.

Pl. LXIII, figs. 5 and 6.

Shell large, irregularly ovate in outline, but varying considerably in this respect; valves subequal, the right one being usually slightly convex and the left flattened or a little concave in the middle; test unusually thick; surface with obscure radiating plications and irregular pits.

An average specimen measures 52 mm. in length, 39 mm. in breadth, and 19 mm. in greatest convexity of the two valves united.

Internal casts show impressions of the characteristic hinge of Plicatula.

Locality and position.—In the same bed with the preceding species, 1 mile southeast of Lower Lake, where it is abundant, but usually not well preserved.

Genus LIMA Bruguière.

LIMA MULTIRADIATA Gabb.

Pl. LXIII, figs. 7 and 8.

Lima multiradiata Gabb, 1869, Paleontology of California, Vol. II, p. 201, pl. 33, fig. 101.

Shell large, less oblique than is usual in the genus, subovate in outline, moderately convex; ears triangular, relatively small, but distinct from the body of the valve, posterior side forming an irregular curve from the ear to the base, most convex below the middle; anterior margin nearly straight or very slightly concave above the ear and forming a regular curve with the base below; surface covered with numerous, slightly sinuous, irregular radiating ribs, which are broader than the very narrow interspaces on the umbonal region, but become relatively more narrow toward the base. The ribs are crossed by rather prominent subsquamose lines of growth, giving parts of the surface a reticulated appearance.

An average specimen measures 61 mm. in greatest length from beak to base and 49 mm. in greatest transverse diameter below the middle of the shell.

The species was originally described from a single fragmentary specimen found in the "intermediate beds" 1 mile southeast of Lower Lake, Cal. The specimens now figured were obtained at the same place, where the species is common, but not very well preserved, associated with *Brachysphingus liratus, Leda alæformis*, and other characteristic Lower Tejon fossils.

Genus CUCULLÆA Lamarck.

CUCULLÆA MATTHEWSONI Gabb.

Pl. LXIV, figs. 4 and 5.

Cucullæa matthewsoni Gabb, 1869, Paleontology of California, Vol. I, p. 195, pl. 31, fig. 266.

Shell large, gibbous, subquadrate, with prominent beaks and a broad cardinal area bearing three or four angular impressed lines; front broadly rounded; posterior end obliquely truncate above, narrowly rounded below; ventral margin in the adult usually slightly sinuous behind the middle; surface in the young shell marked by numerous subequal rather prominent radiating ribs with narrow interspaces. In the adult the ribs are not so regular and they are most conspicuous on the middle region of the shell, becoming obsolete on the posterior end. The surface is also marked by fine lines of growth. Free margins of the valve crenulate within.

The dimensions of a large specimen are as follows: Length, 70 mm.; height, 62 mm.; convexity of valve, 25 mm.

The species varies considerably in outline, the type of the species as figured by Gabb being an unusually short specimen, while the larger one here figured shows the other extreme of variation in length, thus approaching *C. truncata* Gabb in form, though easily distinguished from it in sculpture and other features.

Locality and position.—The figured specimens are from the Lower Tejon beds, 1 mile southeast of Lower Lake. It occurs at Army Point, near Benicia, in the same horizon. Gabb's types were from Martinez and below the coal near Clayton, referred in the one case to the Martinez group and in the other to the intermediate beds, but doubtless both belonging to the same Lower Tejon horizon.

Genus PECTUNCULUS Lamarck.

PECTUNCULUS VEATCHI (Gabb.)

Pl. LXIV, fig. 1.

Axinæa veatchi Gabb, 1864, Palæontology of California, Vol. I, p. 197, pl. 25, figs. 183–183*a*.

The original description of this Chico species is as follows:

"Shell thick, subglobose, equivalve and nearly equilateral; beaks large, incurved, central, approximate, with the sides sloping downward, anterior and basal margins regularly rounded; posterior end rounded or subtruncate, surface marked by 36 to 40 radiating ribs, very regular in size, a little the smallest anteriorly and obsolete behind; a faint depression usually exists on the posterior side of the umbones, which passes down and strikes the middle of the posterior margin. Internal margin coarsely crenulated. Hinge robust; teeth arranged radiately, the lateral teeth largest and most widely separated. Area very short and narrow."

The radiating ribs are sometimes narrower than the interspaces and sometimes broader. The length of the shell is a little less than the height. The large specimen figured measures 49 mm. in length, 51 mm. in height, and the convexity of the single valve is about 21 mm.

The species is introduced here for comparison with the large variety in the Lower Tejon.

Locality and position.—Abundant at numerous localities in the Chico of the Sacramento Valley. The figured specimen is from Pentz (formerly called Pence's Ranch). Some of the small imperfectly preserved specimens from the Tejon usually referred to *P. sagittatus* may belong to this species.

Pectunculus veatchi var. major n. var.

Pl. LXIV, figs. 2 and 3.

Compared with the typical form of the species, this variety is larger, less convex, and proportionally longer; the ribs are broader than the interspaces and the posterior end is more sinuous.

Length of a large specimen, 65 mm.; height, 64 mm.; convexity of one valve, about 22 mm.

Locality and position.—Common in the Lower Tejon 1 mile southeast of Lower Lake. There is one specimen in the California State Mining Bureau collection, obtained by Fairbanks on Point Loma, near San Diego, which is supposed to have come from the Chico.

Genus LEDA Schumacher.

Leda alæformis (Gabb).

Pl. LXIV, figs. 6 and 7.

Corbula alæformis Gabb, 1869, Palæontology of California, Vol. II, p. 177, pl. 29, fig. 63.

The original description of this species is as follows:

"Shell large, broadly rounded in advance, narrow, produced, and truncated behind; beaks about a third of the length from the anterior end, high; posterior cardinal margin nearly straight, bordered by a broad, deep groove extending from the beaks to the posterior end; base prominently and broadly rounded in the middle, sinuous behind; surface marked by small, regular ribs."

It is necessary to add to this description only that internal casts show the characteristic nuculoid hinge, and that the species is unusually convex for a Leda. The abundant occurrence of this Leda at the type locality of Gabb's *Corbula alæformis* and its exact agreement in form and surface sculpture leave no doubt as to its identity.

A large specimen measures 52 mm. in length, 24 mm. in height, and about 8 mm. in convexity of the single valve.

Locality and position.—The figured specimens are from the Lower Tejon 1 mile southeast of Lower Lake, Cal. It has also been collected from the same horizon near Benicia and Pacheco.

Leda gabbi (Conrad).

Pl. LXIV, fig. 8.

Leda protexta? Gabb, 1864, Palæontology of California, Vol. I, p. 199, pl. 26, fig. 185. Not *Leda protexta* Gabb, 1860, Jour. Acad. Nat. Sci. Phila., 2d series, Vol. IV, p. 397, pl. 68, fig. 35.

Nuculana Gabbi Conrad, 1866, Smithsonian Check List Invert. Foss. of North America, Eocene and Oligocene, p. 3.

Leda Gabbi (Conrad) Gabb, 1869, Palæontology of California, Vol. II, p. 197.

This is another large species of Leda, originally supposed to be identical with *Leda protexta*, an Upper Cretaceous species of the Atlantic and Gulf border region. Compared with *L. alæformis*, it is much more slender, less convex, and has finer sculpture. The posterior end is proportionally less narrowed.

A medium-sized specimen measures 24 mm. in length and 10 mm in height, and the convexity of a single valve is about 2 mm.

Locality and position.—The specimen figured is from the Lower Tejon at the brickyard three-fourths of a mile east of Lower Lake, Cal. It is reported from many other Tejon localities.

Genus CRASSATELLA Lamarck.

Crassatella unioides n. sp.

Pl. LXV, figs. 1 and 2.

Shell large, thick, very much elongated, with prominent, almost terminal, beaks; anterior end broadly rounded; posterior end also rounded, but much narrower; dorsal margin sloping regularly from the beaks to the posterior end; ventral margin almost straight; surface showing only lines of growth, but revealing radiating lines toward the front when slightly exfoliated; lunule cordate, rather deep; free margins denticulate within.

Length, 82 mm.; height near anterior end, 49 mm.; convexity of one valve, 20 mm.

The nearest relative of this species is *Crassatella lomana* Cooper,[1] from supposed Chico beds on Point Loma, near San Diego. *C. unioides* is a more slender form, with more prominent beaks, straighter dorsal margin, and narrower posterior end.

Locality and position.—From the Lower Tejon 1 mile southeast of Lower Lake, Cal. Represented by two valves.

[1] Bull. California State Mining Bureau No. 4, 1894, p. 48, pl. 3, fig. 47.

Genus LUCINA Bruguière.

LUCINA TURNERI n. sp.

Pl. LXV, figs. 6 and 7.

Shell large, thick, moderately convex, subcircular in outline; beaks rather prominent; lunule small; surface nearly smooth, marked only by lines of growth, except in the posterior dorsal region, where there is a narrow but distinct furrow, bordered above by a somewhat broader rounded ridge extending from near the beak to the posterior end; dorsal margin slightly excavated in front of the beaks.

The left valve has two well-developed cardinal teeth and obsolescent anterior and posterior laterals.

Length, 52 mm.; height, 49 mm.; convexity of single valve, about 12 mm.

In external aspect this species has some resemblance to *Dosinia elevata* Gabb,[1] but it is not probable that they are congeneric, though I have not been able to study specimens of Gabb's species. None of the fossil species of Lucina described from the Pacific Coast are closely related to this one.

The name is given in honor of Mr. H. W. Turner, of the United States Geological Survey.

Locality and position.—Lower Tejon 1 mile southeast of Lower Lake, Cal.

Genus MERETRIX Lamarck.

MERETRIX sp.

Pl. LXV, figs. 3 and 4.

One of the most abundant species at the locality 1 mile southeast of Lower Lake is a venerid apparently belonging to the genus Meretrix and closely resembling the original figure of *M. hornii* Gabb,[2] but as Gabb discredited that figure when it was published, and his later figure and the specimens preserved in the Academy of Natural Sciences, Philadelphia, are not at all like it, our fossils can not be identified with his species. Possibly this will prove to be a new species, but I shall not venture to name it until several of Gabb's venerid species represented by conventionalized figures are better known. It may be described as follows:

Shell subtriangular, moderately convex, with thin test; beaks prominent, considerably in advance of the middle; lunule small, deeply impressed; dorsal margin slightly convex behind the beak, sloping rapidly to the narrowly rounded posterior end; anterior end broadly rounded; ventral margin forming a regular curve; surface marked by

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[1] Palæontology of California, Vol. I, pl. 30, fig. 252.

[2] Ibid., pl. 23, fig. 144.

closely arranged, rather prominent concentric ridges and furrows, which vary considerably in size.

The numerous specimens collected show considerable variation in relative length of the shells, but this feature does not seem sufficiently constant for specific separation.

The dimensions of the largest specimen are: Length, 43 mm.; height, 31 mm.; convexity of single valve, about 8 mm. The corresponding measurements of a smaller specimen of the short variety are 27, 23, and 6 mm., respectively.

Genus TELLINA Linnæus.

TELLINA HORNII Gabb?

Pl. LXV, fig. 5.

Tellina hornii Gabb, 1864, Palæontology of California, Vol. 1, p. 160, pl. 30, fig. 244.

A slender, compressed, thin-shelled form agreeing fairly well with Gabb's figure of this species. The beaks are small, median in position; anterior end regularly rounded; posterior end obliquely subtruncate above, narrowly rounded below; ventral margin almost straight; surface marked only by irregular lines of growth.

Length, 40 mm.; height, 20 mm.; convexity of single valve, about 2 mm.

It is by no means certain that this species is a Tellina. It has been referred to Psammobia by Heilprin, and may belong there, but in the absence of knowledge of the hinge and other internal features, it is thought better to leave it under the original name.

Locality and position.—The type is from Tejon strata near Fort Tejon. The specimen now figured was obtained in the Lower Tejon 1 mile southeast of Lower Lake, Cal.

Genus TURRITELLA Lamarck.

TURRITELLA PACHECOENSIS n. sp.

Pl. LXVI, figs. 1 and 2.

Turritella saffordii Gabb, 1864, Palæontology of California, Vol. I, p. 135, pl. 2, fig. 93. Not *Turritella saffordi* Gabb, 1860, Jour. Acad. Nat. Sci. Phila., 2d series, Vol. IV, p. 392, pl. 68, fig. 12.

Adult specimens with 18 or 20 whorls that are flattened on the sides and more or less angulated above and below near the channeled suture; surface of the earlier whorls marked by about 12 fine spiral lines, of which those on the angles near the sutures are most prominent; on later whorls the spiral lines become obsolete and the sinuous lines of growth become much more prominent, forming rows of obscure tubercles on the angles; aperture subquadrate.

A large specimen consisting of 10 whorls, but lacking the apical portion, measures 122 mm. in length and 33 mm. in greatest breadth. Another specimen, consisting of the upper 11 whorls, is 31 mm. in length and 9 mm. in greatest breadth.

The earlier whorls of this species have considerable resemblance to the Tennessee Cretaceous forms to which the name *T. saffordi* was originally applied, but when adult specimens are compared they are seen to have very little in common. There is considerable variation in the extent to which the tubercles are developed on the later whorls, but indications of these are always found.

Locality and position.—Abundant in the Lower Tejon 2½ miles northeast of Lower Lake and rare 1 mile southeast of that village. The specimens figured are from the same horizon 1 mile north of Pacheco, Cal. Gabb reports it from near Martinez and Lower Lake and 6 miles northeast of Suisun, Cal. Doubtless all of these localities are on the same horizon, though two of them were referred to the Martinez group.

Turritella infragranulata Gabb.

Pl. LXVI, fig. 3.

Turritella infragranulata Gabb, 1864, Palæontology of California, Vol. I, p. 212, pl. 32, fig. 279.

Shell rather large, composed of 12 or 15 whorls, which are strongly angulated below, broadly excavated above, and again prominent near the linear suture; surface marked by 9 or 10 fine spiral lines and by numerous granulations or small tubercles on the lower angle of the whorl.

The figured specimen, which lacks several whorls at the apex, measures 63 mm. in length and 21 mm. in greatest breadth. Other imperfect specimens indicate that the species attained dimensions almost twice as great.

The apical angle of this species is considerably greater than that of *T. pachecoensis*. Another, perhaps more closely related, species in the same beds is *T. martinezensis* Gabb, which has about the same proportions, but differs in form of whorl and surface sculpture.

Locality and position.—The type of the species was obtained near Martinez and doubtfully referred to the Martinez group. The specimen now figured was obtained in the Lower Tejon 1 mile north of Pacheco, Cal., and others were collected at Army Point, near Benicia, and 1 mile southeast of Lower Lake, all from the same horizon.

Genus LUNATIA Gray.

Lunatia hornii Gabb.

Pl. LXVI, fig. 4.

Lunatia hornii Gabb, 1864, Palæontology of California, Vol. I, p. 106, pl. 29, fig. 217.

Original description.—"Shell subglobose; spire small, acute, not prominent; whorls five, almost entirely enveloped, except the newer portions of the penultimate volution. Aperture semilunar, rounded below; outer lip acute, nearly straight; columellar lip with a moderately large callus, thickened above, smaller and flat below, continuing as a thickened lip almost to the anterior end of the mouth. Umbilicus small, partially covered. Surface marked by irregular lines of growth."

Locality and position.—The types are from Alizos Creek, near Fort Tejon, in beds probably belonging to the Upper Tejon. The specimen figured is one of a number obtained from the Lower Tejon 1 mile southeast of Lower Lake. They have been compared with examples from the original locality and seem to be identical.

Genus PERISSOLAX Gabb.

PERISSOLAX BLAKEI (Conrad).

Pl. LXVII, fig. 1.

Busycon? blakei Conrad, 1855, Pacific Railroad Reports, Prelim. Geol. Rept. of W. P. Blake, p. 11; 1856, idem, Vol. V, p. 322, pl. 2, fig. 3.

Levifusus blakei Conrad, 1866, Smithsonian Check List Invert. Foss. of N. A., Eocene and Oligocene, p. 19.

Perissolax blakei (Conrad) Gabb, 1864, Palæontology of California, Vol. I, p. 92, pl. 21, fig. 110; 1869, idem, Vol. II, p. 149.

Shell consisting of about 6 rapidly increasing shouldered whorls, with a single slightly tuberculated carina visible on the spire and three on the body whorl; suture linear; spire covered with minute spiral lines; canal long and nearly straight with coarser spiral lines; upper whorls more or less cancellate.

The specimen figured, which has a lower spire and shorter canal than the average, measures 40 mm. in length and 25 mm. in breadth.

The type of the species came from the neighborhood of Fort Tejon, and the slender form figured by Gabb is abundant in the Tejon beds above the coal east of Clayton. These show only two carinæ on the body whorl instead of three, but Gabb mentions a specimen from Martinez that had three angles like the present one, which is from the Lower Tejon at Army Point, near Benicia.

Genus STREPSIDURA Swainson.

STREPSIDURA PACHECOENSIS n. sp.

Pl. LXVII, fig. 2.

Shell of medium size, broadly fusiform; spire rather low, sloping regularly from the angle, which is above the middle of the body whorl; suture linear, appressed; canal about as long as the spire and abruptly bent near the end; surface marked by numerous closely arranged thread-like lines, mostly alternating in size, and by broad, rather obscure plications on the angle of the body whorl.

Length, 45 mm.; greatest breadth, 35 mm. The single type specimen is somewhat exfoliated, so that the surface sculpture is not very well preserved.

Locality and position.—Lower Tejon 1 mile north of Pacheco, Cal., where it is associated in the same layer with *Turritella pachecoensis.*

Genus HETEROTERMA Gabb.

Heteroterma striata n. sp.

Pl. LXVII, fig. 5.

Shell broadly fusiform, consisting of about 5 whorls, that are somewhat concave above; sutures linear, undulated; spire about one-third the length of the shell, with an apical angle of nearly 90°; canal about the length of the spire, straight and relatively narrow, sharply distinct from the rest of the body whorl, which bears on its middle portion very prominent short costæ or elongated tubercles that in the later stages of growth sometimes show a tendency to divide into two rows of nodes; surface of entire shell also marked by rather coarse linear striæ, separated by broader interspaces.

Length, 27 mm.; greatest breadth, 22 mm.

In general form this species is very much like the type of the genus, *Heteroterma trochoidea*, which came from Martinez and was credited to the Martinez group, so that it probably also belongs to the Lower Tejon fauna. *H. trochoidea* differs from *H striata* in having its body whorl distinctly bicarinate, with a row of tubercles on each carina, and in having much more numerous and finer spiral lines. These distinctions are well shown in the figures and are confirmed by direct comparison of the types.

Locality and position.—Lower Tejon 1 mile north of Pacheco, and small specimens probably of same species 1 mile southeast of Lower Lake.

Heteroterma gabbi n. sp.

Pl. LXVII, fig. 3.

Shell large, short fusiform; spire low, with the smooth upper portion of the whorls concave between the undulating sutures; body whorl large, angulated a little above the middle, abruptly contracted into the short beak below; slope above the angle slightly concave and marked only by fine lines of growth and minute revolving lines; middle of body whorl with about 12 or 13 short, prominent, longitudinal plications crossed by 8 or 9 strong revolving lines, beneath which the surface is again almost smooth, with a few inconspicuous revolving lines.

Length, 44 mm.; greatest breadth, 35 mm.

The lines of growth indicate that there was a posterior sinus of the aperture, as in *H. trochoidea.*

In Gabb's collections from the "intermediate beds" near Lower Lake, the young of this or the preceding species was probably identified as *Perissolax brevirostris*, to which it has a slight superficial resemblance. A specimen of the latter species from the Chico, near Pentz, Cal., is figured for comparison (Pl. LXVII, fig. 4).

Genus SIPHONALIA A. Adams.

SIPHONALIA? LINEATA n. sp.

Pl. LXVII, fig. 7.

Shell small, short fusiform, with a strongly twisted canal; spire short, consisting of 4 or 5 whorls; body whorl large, rounded; canal a little longer than the spire; surface covered with thread-like spiral lines crossed by rather prominent lines of growth; on the spire and the upper part of the last whorl 2 or 3 of the spiral lines are considerably larger than the others that alternate with them.

Length of an average specimen, 17 mm.; greatest breadth, 11 mm.

Locality and position.—In the Lower Tejon 1 mile north of Pacheco (the figured specimen) and 1 mile southeast of Lower Lake, Cal.

Genus UROSYCA Gabb.

UROSYCA CAUDATA Gabb.

Pl. LXVII, fig. 6.

Urosyca caudata Gabb, 1869, Palæontology of California, Vol. II, p. 159, pl. 27, fig. 38.

Original description.—"Shell moderately large, pyriform; spire low; whorls 5, the upper rounded, the body whorl subangulated by three nearly equidistant, nodose, revolving carinæ; top of whorl slightly sloping, interspaces between the ribs slightly concave, anterior portion deeply excavated. Surface crossed by numerous small revolving striæ. Aperture broad; outer lip simple, inner lip slightly incrusted; canal long, slender, slightly twisted.

"Length, 2.35 inches; length of aperture, 2.15 inches; width of body whorl, 1.3 inches.

"Rare in the Martinez group, Martinez."

The figure of the type is considerably restored and represents an unusually large specimen. The example figured in this paper is smaller and has suffered some distortion by pressure, especially in reducing the height of the spire, but it has been compared and fully identified with the types of the species in the Philadelphia Academy.

Locality and position.—The figured specimen is from the Lower Tejon at Army Point, near Benicia, where the species is abundant. It is also common in beds of the same age near Lower Lake, and one specimen was collected 1 mile north of Pacheco.

Genus BRACHYSPHINGUS Gabb.

BRACHYSPHINGUS LIRATUS Gabb.

Pl. LXVI, figs. 5 and 6.

Buccinum liratum Gabb, 1864, Palæontology of California, Vol. I, p. 96, pl. 28, fig. 211.
Brachysphingus liratus Gabb, 1869, idem, Vol. II, p. 156.

Original description.—"Shell ovoid, robust, test thick; spire low, whorls 4½ to 5, convex; aperture elongate, deeply notched in advance; outer lip simple; inner lip slightly incrusted, more heavily below than above; umbilicus distinct, but imperforate; surface marked by numerous rounded, longitudinal ribs, with intermediate spaces somewhat smaller than the ribs themselves; these run somewhat obliquely, especially at the top, where they curve slightly from behind forward. The lower third to half of the shell is marked by numerous small revolving impressed lines."

Some specimens, especially of young shells, show revolving lines over the whole surface. There is a well-marked siphonal fasciole, bordered by a sharp ridge.

A medium-sized specimen measures 31 mm. in length and 23 mm. in greatest width.

Locality and position.—The figured specimens are from the Lower Tejon 1 mile southeast of Lower Lake, Cal., where the species is abundant. It occurs more sparingly in the same horizon near Benicia and 1 mile north of Pacheco. The localities given in Gabb's original description are Martinez, Clayton, and Marsh's Ranch, all in the Mount Diablo region.

PLATES.

PLATE LXIII.

PLATE LXIII.

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Flabellum remondianum Gabb 1036

Fig. 1. Side view enlarged.

Fig. 2. Enlarged cross section of another specimen, showing arrangement of septa. (The three septa of the sixth cycle in the half systems adjoining the termini of the longer transverse axis may not be present.)

Terebratulina tejonensis n. sp 1037

Fig. 3. Slender ventral valve, slightly distorted.

Fig. 4. A large dorsal valve.

Plicatula ostreiformis n. sp 1038

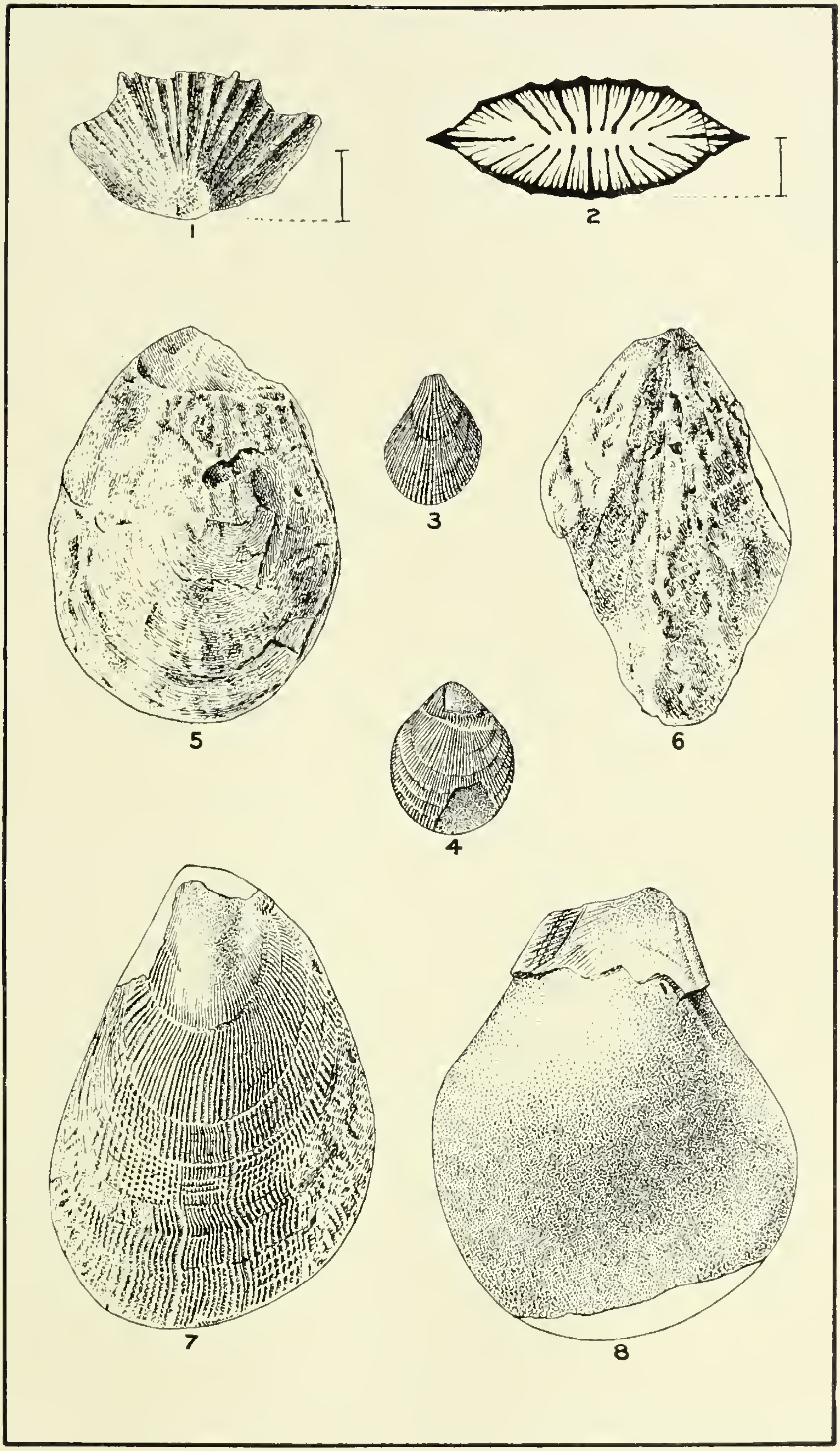
Fig. 5. A medium-sized right valve.

Fig. 6. More slender right valve, with the lower margin broken.

Lima multiradiata Gabb 1038

Fig. 7. Slender left valve, showing surface sculpture from gutta-percha cast of a natural mold.

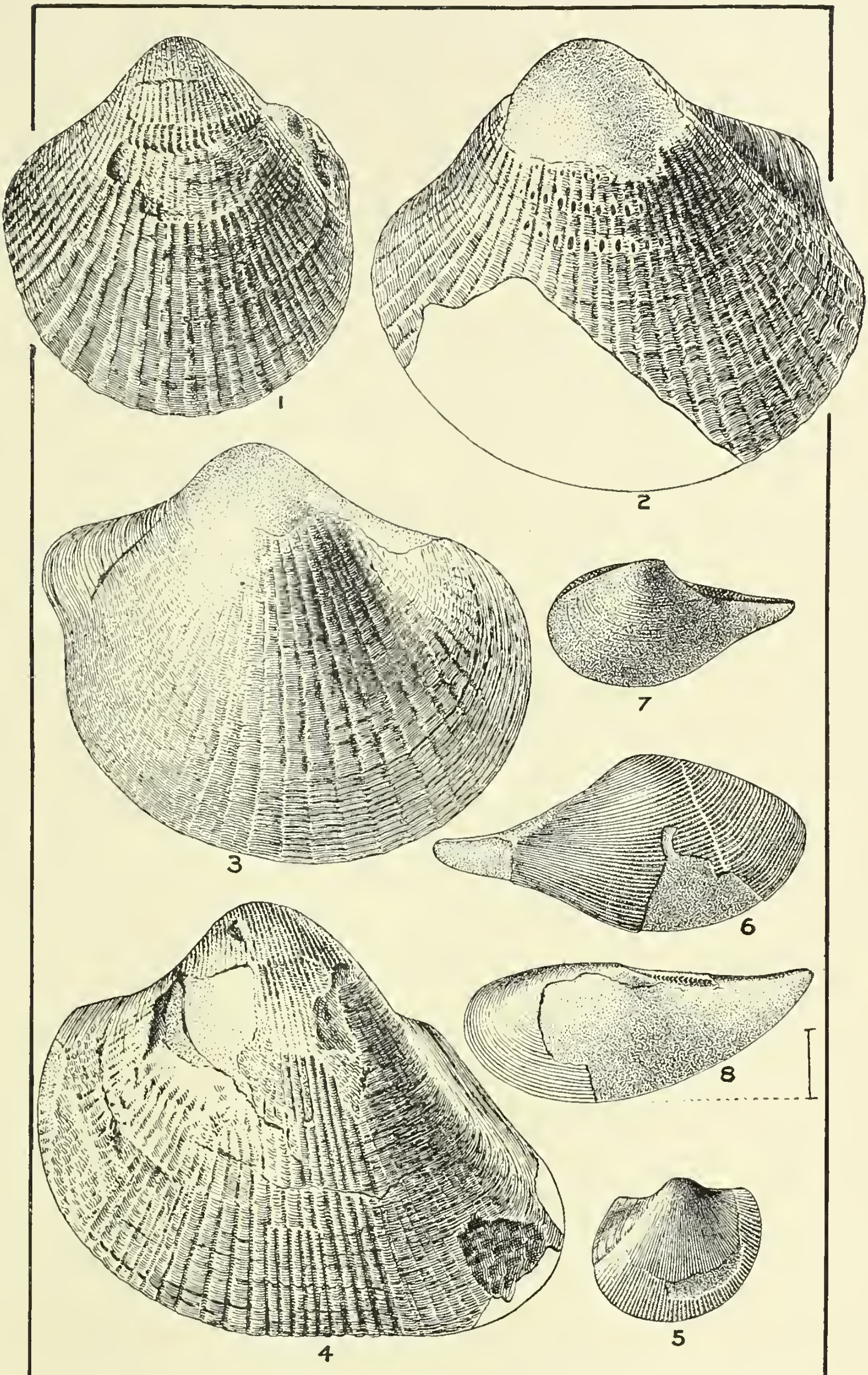
Fig. 8. Cast of a broader right valve retaining shell on the beak and ears.



LOWER TEJON INVERTEBRATA.

PLATE LXIV.

PLATE LXIV.



LOWER TEJON AND CHICO PELECYPODA.

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PLATE LXV.

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CRASSATELLA UNIOIDES n. sp.	1041
Fig. 1. Side view of large left valve.	
Fig. 2. Anterior view of same.	
MERETRIX sp.	1042
Fig. 3. A large elongate right valve.	
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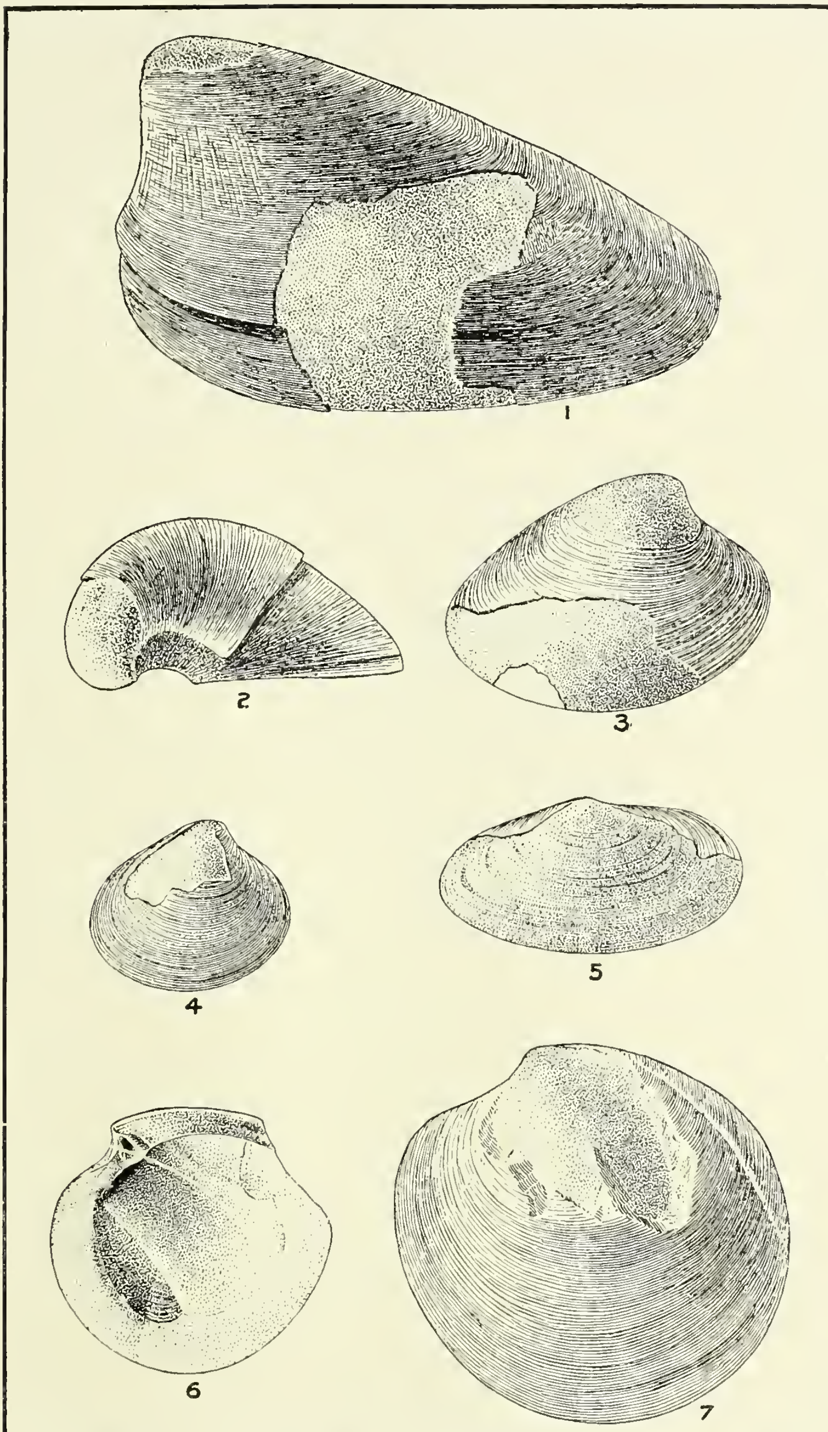
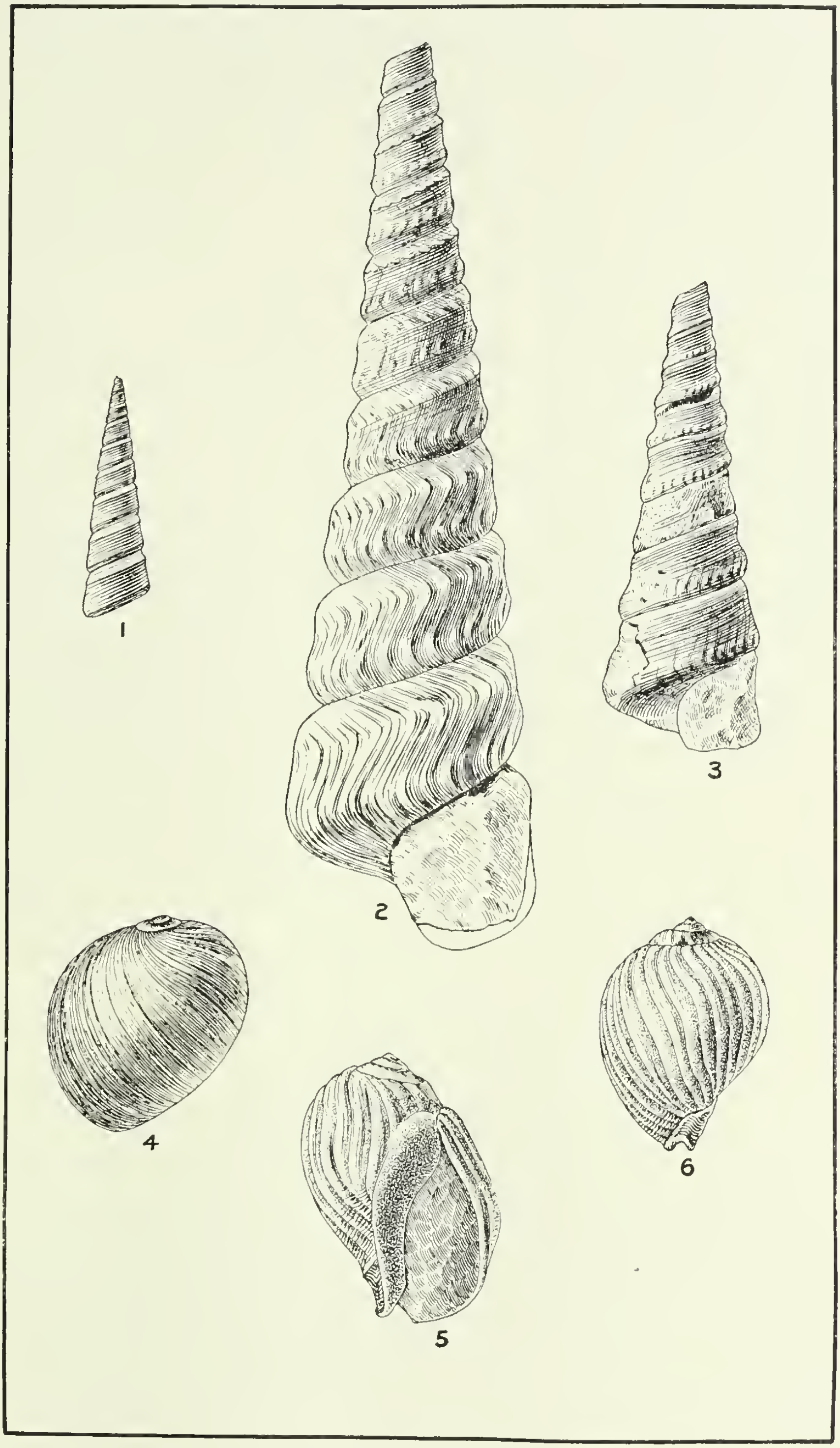
TELLINA HORNII Gabb?	1043
Fig. 5. Internal cast of right valve, retaining a little of the shell.	
LUCINA TURNERI n. sp.	1042
Fig. 6. Interior of small right valve from gutta-percha impression of natural cast.	
Fig. 7. A large left valve.	



LOWER TEJON PELECYPODA.

PLATE LXVI.

PLATE LXVI.

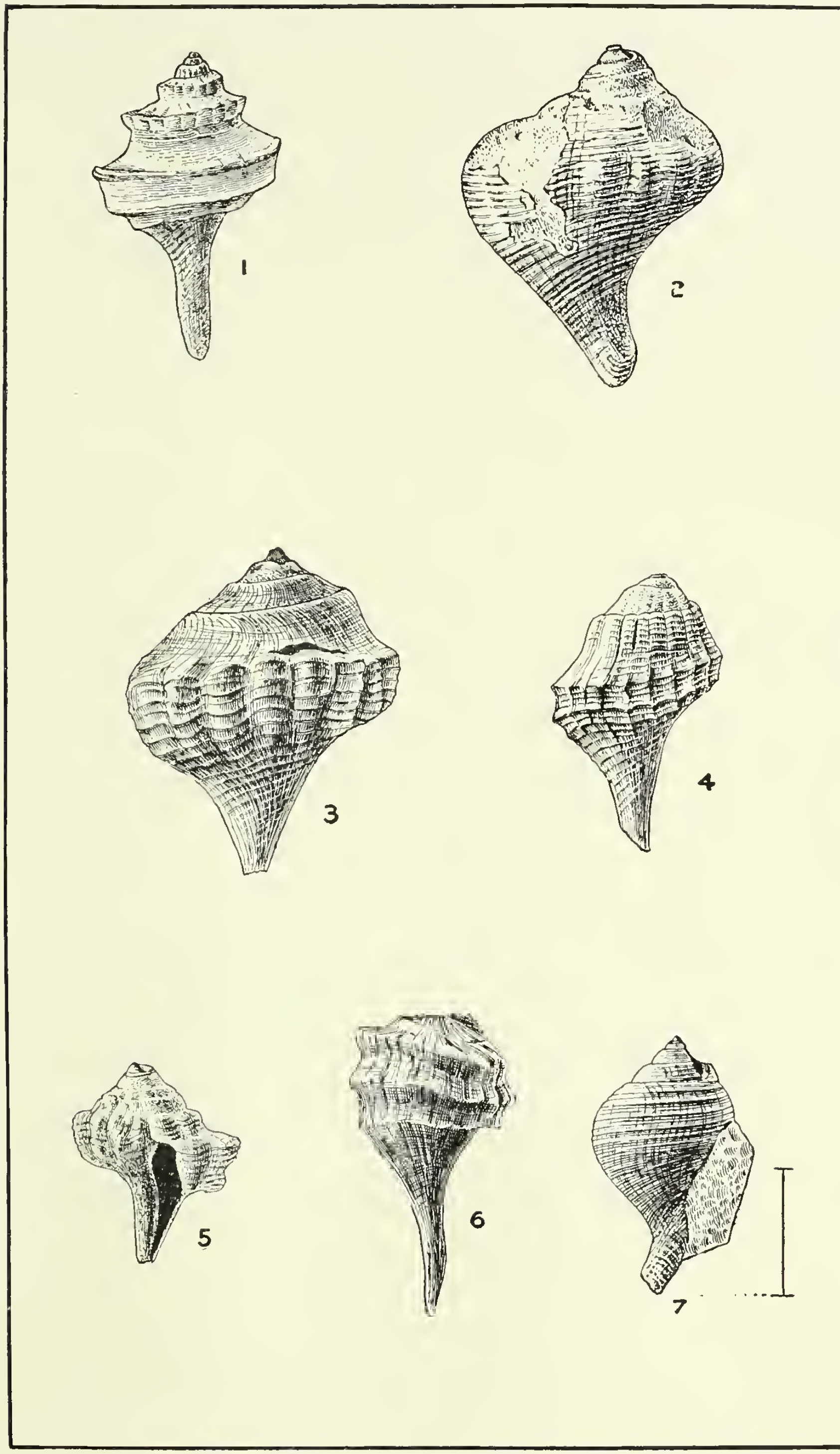


LOWER TEJON GASTROPODA.

PLATE LXVII.

1059

PLATE LXVII.



LOWER TEJON AND CHICO GASTROPODA.

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[Seventeenth Annual Report.]

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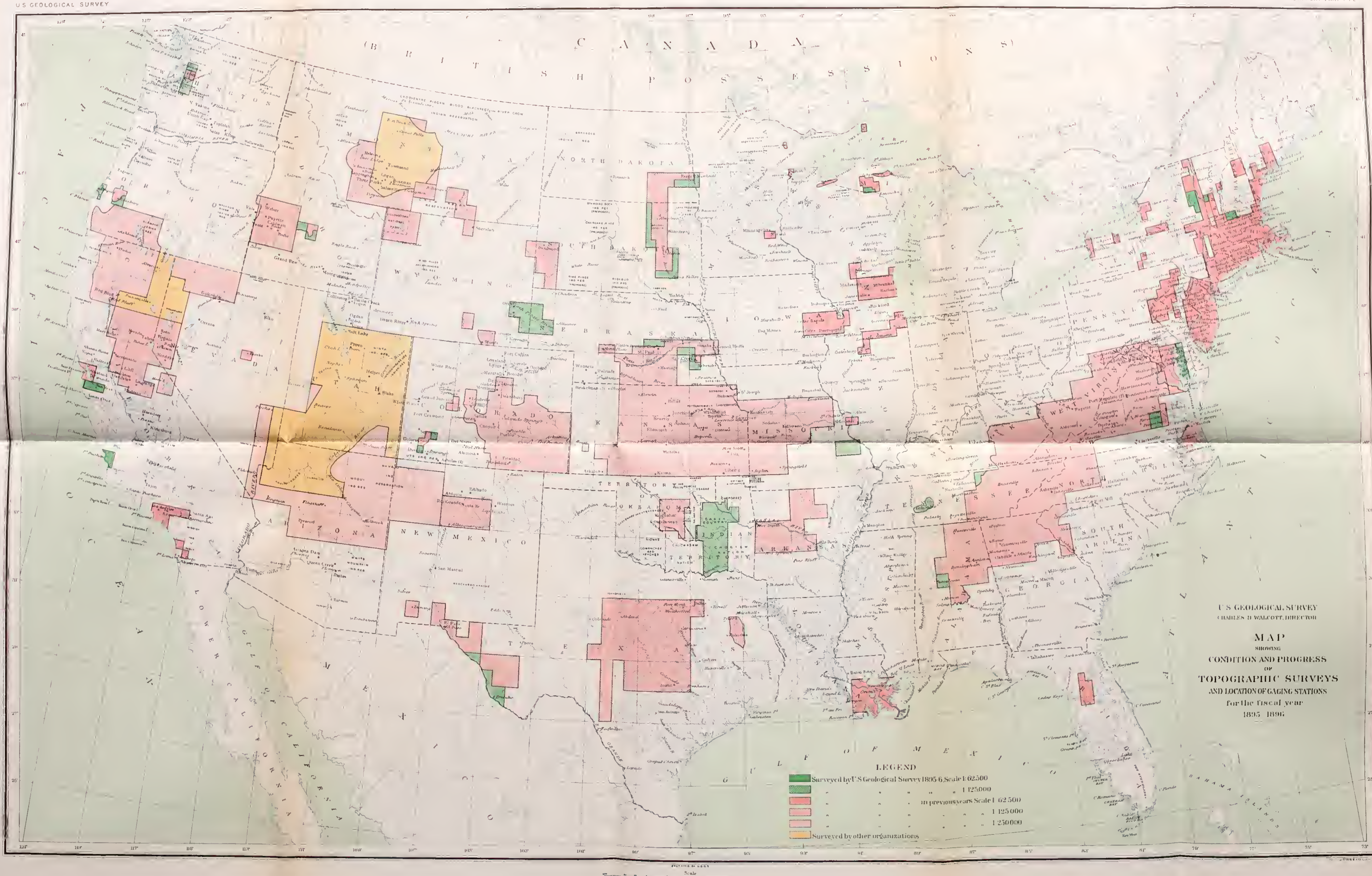
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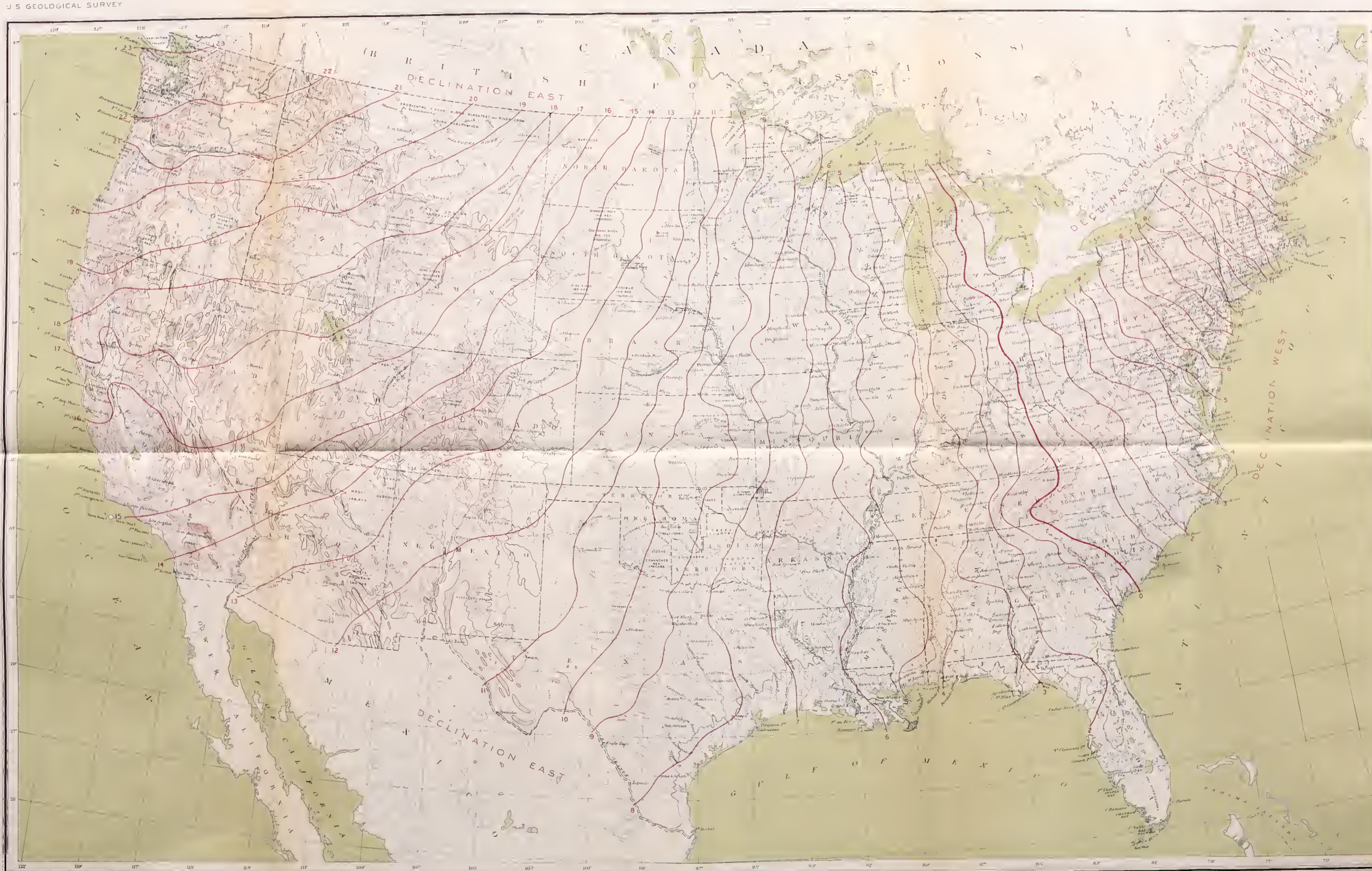
KANSAS
MISSOURI
IOWA
ARKANSAS
INDIAN TERRITORY
TEXAS
LOUISIANA
MISSISSIPPI
TENNESSEE
GEORGIA
SOUTH CAROLINA
NORTH CAROLINA
WEST VIRGINIA
PENNSYLVANIA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
GULF OF CALIFORNIA
LOWER CALIFORNIA
MEXICO
BAHAMA ISLANDS
U S GEOLOGICAL SURVEY
CHARLES D WALCOTT, DIRECTOR
MAP
SHOWING
CONDITION AND PROGRESS
OF
TOPOGRAPHIC SURVEYS
AND LOCATION OF GAGING STATIONS
for the fiscal year
1895 1896
LEGEND
Surveyed by U.S Geological Survey 1895-6, Scale 1: 62500
" " " " " 1 125000
" " " in previous years Scale 1 62 500
" " " " " " 1 125000
" " " " " " 1 250000
Surveyed by other organizations
Scale

2



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DISTRIBUTION OF THE MAGNETIC DECLINATION IN THE UNITED STATES IN 1900.

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