New York State Education Department

NEW YORK STATE MUSEUM

66th ANNUAL REPORT

1912

In 3 volumes

VOLUME 1

REPORT OF THE DIRECTOR 1912

AND

APPENDIX 1

TRANSMITTED TO THE LEGISLATURE MARCH 16, 1914

ALBANY
THE UNIVERSITY OF THE STATE OF NEW YORK
1914

STATE OF NEW YORK

EDUCATION DEPARTMENT

State of New York

No. 43

IN ASSEMBLY

March 16, 1914

66th ANNUAL REPORT

OF THE

NEW YORK STATE MUSEUM

VOLUME 1

March 18, 1913

To the Legislature of the State of New York

We have the honor to submit herewith, pursuant to law, as the 66th Annual Report of the New York State Museum, the report of the Director, including the reports of the State Geologist and State Paleontologist, and the reports of the State Entomologist and the State Botanist, with appendixes.

St Clair McKelway
Vice Chancellor of the University

Andrew S. Draper
Commissioner of Education

CONTENTS

VOLUME 1

Report of the Director 1912

Appendix 1

Museum Bulletins 168, 169, 170

VOLUME 2

Appendixes 2-5

Museum Bulletins 166, 165, 167, 163

VOLUME 3

Appendix 6

Museum Memoir 12, volume 2

Appendix 1

Geology and paleontology

Museum Bulletins 168, 169, 170

168 The Geological History of New York State

169 Geology of Saratoga Springs and Vicinity

170 Geology of the North Creek Quadrangle, Warren County, New York

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New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 164

NINTH REPORT OF THE DIRECTOR OF THE SCIENCE DIVISION

INCLUDING THE

66th REPORT OF THE STATE MUSEUM, THE 32d REPORT OF THE STATE GEOLOGIST, AND THE REPORT OF THE STATE PALEONTOLOGIST FOR 1912

New York State Education Department
Science Division, February 13, 1913

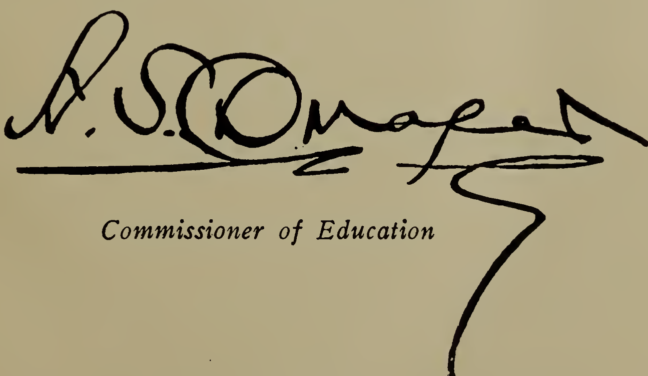
Hon. Andrew S. Draper LL.D.
Commissioner of Education

Sir: I have the honor to transmit herewith the manuscript and accompanying illustrations of the annual report of the Director of the Science Division, for the fiscal year ending September 30, 1912, and I recommend the same for publication as a bulletin of the State Museum.

Very respectfully
John M. Clarke
Director

STATE OF NEW YORK
EDUCATION DEPARTMENT
COMMISSIONER'S ROOM

Approved for publication this 19th day of February 1913



Commissioner of Education

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John M. Clarke, Director

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NINTH REPORT OF THE DIRECTOR OF THE SCIENCE DIVISION

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INTRODUCTION

This report covers all divisions of the scientific work under the charge of the Education Department and concerns the progress made therein during the fiscal year 1911–12. It constitutes the 66th annual report of the State Museum and is introductory to all the scientific memoirs, bulletins and other publications issued from this office during the year mentioned.

Under the action of the Regents of the University (April 26, 1904) the work of the Science Division is "under the immediate supervision of the Commissioner of Education," and the advisory committee of the Board of Regents of the University having the affairs of this division in charge are the Honorables: Daniel Beach LL.D., Watkins; Lucius N. Littauer B.A., Gloversville; Adelbert Moot, Buffalo.

The subjects to be presented in this report are considered under the following chapters:

I

THE STATE MUSEUM LAW

The present attitude of the State of New York toward its museum is defined in the statute enacted in 1889 and incorporated without change in the codified Education Law of 1910:

All scientific specimens and collections, works of art, objects of historic interest and similar property appropriate to a general museum, if owned by the State and not placed in other custody by a special law, shall constitute the State Museum.

This provision for the existence of a State Museum is brief and precise, but the conception which lies behind it is broad, enlightened and efficient. Provision is made, not alone for a museum of science, even though to the present day the science museum only has received recognition and support by actual allotments from the Legislature. The law is broader than the present exercise of that law and the genius of the brief enactment cited rises above the actual condition attained by virtue of it.

THE STATUTORY CONCEPTION OF A "STATE MUSEUM"

The letter and evident spirit of the law provide not only for the museum that now exists, but for any public museum which the people of the State may choose to bring into existence, whether it be a museum of history, of art, of industry, or of education; and all such museums and their materials shall constitute the *State Museum.* The statute clearly opens the way for the institution, at the will of the people, of a series of museums or departments of a State Museum, as many in number and nature as the reasonable demands of a populous, wealthy and intellectual state may regard essential to the instruction of its people. No law for the establishment of public museums could be broader in import or susceptible of a more generous interpretation in strict accord with the expressed wishes of the people. It is the deliberate expression of the Legislature of the State that a place be provided in its polity, not alone for the museum of science, which has been in existence for sixty years, but for additional museums, as their need may become appreciated, all under the control of the Education Department. This is clearly the meaning of a law which, in state legislation on this subject, is not surpassed for conciseness and breadth.

THE STATE MUSEUM IDEA AND ITS PLACE IN THE POLITY OF THE STATE

This State has thus far developed its magnanimous conception of the *Museum* only along the line of science. So far as it has gone it has doubtless done well in this single direction, for its museum of science has brought credit to it and to those who have shared in its development. The State Museum of Natural History has achieved a distinctive and worthy repute among such scientific museums whose interests are of necessity somewhat restricted by political boundary lines. It is very doubtful if any state museum of science should attempt to enter the wider field of the world and thus compete with the great privately endowed museums of the larger municipalities. Its function is well and adequately defined in portraying in fulness the natural resources of its state. The good repute of the New York State Museum of science has come, however, more from the work of original research which it has fostered, than from the educational service thus far rendered through its collections. These collections have been assembled very largely for the service of the investigations, rather than with the purpose of elucidating to the people the significance of these researches. So far is this the case that the science museum, now entering a new building with capacious and well-equipped halls, finds itself deficient, not in the quantity but in the quality of scientific materials suitable to display to the public or competent lucidly to explain the facts they represent and the researches which the Museum has prosecuted. This is a condition which must be remedied if this Museum is to become a vigorous arm of the educational service. In a very real sense the science museum, notwithstanding its long history and its large collections, is beginning anew, for never within its history has it possessed a satisfactory *locus*. Its collections have long been scattered through many different buildings. But out of the assembled material now brought together in the Museum halls of the Education Building, is to develop a series of scientific collections in the various departments of natural history here pursued, that will be of effective instructional value entirely creditable to the State.

That a knowledge of a state's natural resources is of paramount moment to the people, needs no argument. That the people should have an insight into the larger scientific problems based upon and arising from these natural resources, will not admit of debate. In the natural and orderly development of practical and intellectual interest among the people, these are demands which have a superior force because they develop first.

But this great Commonwealth has certainly reached a stage of intellectual attainment where it may demand now, or should demand soon, the development of the fuller conception of the additional museums to which the statute has pointed the way. The State of New York has no museum of its own history. Whether it should have is not a matter for debate. The director's project for such a museum has been approved by the Commissioner of Education, by a special committee of the Board of Regents, by unanimous vote of the Board itself, by the finance committee of the Senate and by a thousand expressed opinions of competent citizens. Yet it does not exist. The substantial means fail largely because a *locus* for such a museum still fails. The hope that the Education Building might accommodate such a museum probably must be abandoned for want of room, and until there is a definite answer to the question " Where are you going to put it? " the appropriations necessary for its creation will be withheld. For such an historical museum public sentiment is ripe, and the time is ripe. In the impending amplification of the State's buildings provision should be made for it.

Have the people of the State of New York reached a stage of such intelligent concern in their past as to desire a portrayal of the development of the industries on which their wealth and happiness so largely depend? Has not the time arrived when a museum which would teach the people how the raw material in every line of industry is evolved into the finished product, would have a very distinctive usefulness to all the people? How many among the ten million citizens of New York know that their morning newspaper requires in its manufacture the use of sulfur and lime, and talc or clay as well as wood? One who is concerned with modern methods of any manufacture will be as much concerned in the historical development of that industry. Here lies an immense field of deepest concern and very high instructional value. To such an inspiring institution as a museum of industry, all paths would lead; the direct appeal to the people would be of tremendous force and the response from the people would not fail to be substantial. It is well worth while to consider if the development of this conception in the museum series can wisely be left to a coming generation.

The public art museum is naturally the last to take its place in the development of the public museum idea. Time will bring it to every state as intellectual appreciation and the love of the beautiful advance. Experience has taught this, and the abundance of art museums maintained in the older countries by state grants is evidence that, even though the time may still be unripe in New York, at least its seed has taken root.

A law in which the people have intimated a desire, if not an intention, to develop the museum idea for the State on the broad lines indicated, remains but partially enforced. An intelligent people opened the door for the development of this idea; the conception has been rather too long left unheeded. This State has intimated its willingness to stand for the progressive habilitation of this conception and with the Regents of the University, charged with the enforcement of this law and the right to execute its intentions, lies here an opportunity for additional public service.

II

THE EDUCATIONAL FUNCTION OF THE STATE MUSEUM OF SCIENCE

In rendering the annual account of the procedure in this division during the fiscal year, it seems well to ask special attention from those who may read this report to the requirements of the real educational functions of this organization. Year after year record has been made of the advance of work along the several lines of scientific inquiry and conversation legitimately pursued by it. Data of scientific worth and moment have annually heaped up on the vast accumulation of like facts which the many years of previous work have brought forth; publications have issued in unbroken streams, in which some part of this accumulation of knowledge has been digested and set forth so as to take its proper place in the fabric of science. All the work done and the work begun, whatever its outcome, is to have its final bearing on the progress of the knowledge of this State and its natural resources, howsoever remote its immediate relation thereto may seem.

Not for an instant has the attitude of the chief educational officer, judicially reflecting the underlying sentiment of the State, intimated a purpose to restrain or curtail investigations in those lines of pure and applied science here carried on; on the contrary this influence has substantially favored and appreciatively encouraged all this work, in geology, paleontology, mineralogy, botany, entomology, zoology and archeology; the proper fields of science which this division covers. Such indeed has been the historic attitude of the State toward this work and such without question it is likely to be.

This Division of Science, during its long existence of seventy-five years, has rolled up a monumental record of the varied scientific resources of the State, embodying facts and factors which have modified and added to the total body of science in ways that it would now be difficult to estimate. The State of New York has become classic ground of these scientific branches and its fund of records is in keeping with the vastness of its natural wealth. There could be no justification for any cessation in these activities, whether they pertain to pure or to applied science. The mining production of this State has increased by 3000 per cent since the inception of the Geological Survey. The control of insect depredations upon the agricultural and forest crops of the State becomes annually of greater moment to the people with the yearly enlargement of the crops themselves. The conservation of all our native fauna and flora is a problem of growing concern.

These are but items in the progress of results, but it may be said with security that never in its history has this division been of more immediate usefulness to the progress of the people nor its contributions in pure science of more moment to the philosophy of life. The solution of every problem of science brings with it new and larger problems. The bell never rings on scientific progress and research — if it does, in a State like this, it is a knell that tolls for death and decay. There lie before us today in these various fields of research larger problems, more deeply fraught with the welfare of the Commonwealth, more intimately concerned with the inspiration and uplift of the citizen, than there have ever been.

But in an evident and pregnant sense we have now come to a turn in the road. This division is, and has long and properly been, a part in the University of the State and the Department of Education; and as such its ideals of research have never faltered or been contravened. Now, by virtue of the equipment for it of extensive museum halls, it enters by force and by preference into more immediate and direct touch with the citizens. The burden is laid upon it to bring home to the people, by visual appeal, the meaning of all that has been said and done in science during the years past. The "State Museum" has long been a statutory designation, intimating scientific collections brought together for the exposition of our natural resources but in reality implying and covering the investigations of these resources themselves. At no time in the history of the organization has there been an adequate museum; not once in all its career have the people been able to come into actual touch with the materials on which the published scientific works have been founded or to learn through their own eyes the real meaning of the resources and of the operations of nature which have been portrayed on the thousands of pages and plates of our public reports.

The fact that this time has now arrived, that capacious quarters are about to be fully equipped for the reception of the material objects of science, brings, in effect, a new function to this division — that of making an efficacious and impressive contribution to the education of the people into these sources of knowledge, in a building devoted throughout to the official diffusion of knowledge.

There are certain aspects of this new function that are proper in this public report at a time when the equipment of this museum of science lies just a step ahead. The first of these, first in significance to those on whom this large duty devolves, is the fact that thus far the Museum has been the repository of the materials brought together by men engaged in the solution of scientific problems; these materials are not in any large sense conspicuous objects, carefully selected for special purposes of display, or to tell their own story. The collections of the Museum are very large, as state museums go, but if this large amount of material now contained in thousands of boxes, drawers and cases, were to be so divided that one part should comprise all that would arouse the interests of the inexpert, the latter would be but a slender fraction of the whole.

In the science of paleontology, a science of which the State of New York has for years been the especial patron, this fact is preeminently true. The Museum resources herein are large, but of this large accumulation there is only a small part that can be made to tell its fascinating story to the uninitiated. To consider for a moment the demands of this science alone, and its place in a museum: the people of the State have a right to know what it is all about and why such extraordinary encouragement has been given to its prosecution; how it is that the State of New York has acquired its repute as the exponent of this science, and, if it is true that more is known of the paleontology of this State than of any equal area of the world (as has been said by a distinguished French geologist), where is the proof of this outside of published documents. There are no mysteries in science and the fruits of this knowledge are the property of the people who have paid for it. There is thus laid upon this division the acquisition of materials in this field of science, that will tell the story of the life in the seas and on the lands of ancient New York, its beginning, its development and its outcome, and tell it in a way so lucid and intelligible that the visitor to the Museum can read it and learn it. No good thing, therefore, that can make clearer the wonderful history of life in this part of our ancient earth, and so help to enforce the broader lessons of the life from which we have derived our own existence, can be sacrificed or neglected, for so simply gross a reason as that appropriations for this work are inadequate. A scientific specimen in a labratory and such a specimen in a museum are of two vastly unlike qualities. The one tells its story to the expert, the other must be made to tell its simple and clear story to the larger world.

What has thus been intimated with reference to this science of paleontology may be said with equal appropriateness of all cognate sciences. Each has its meaning as a factor in the education of all the people.

It is to this factor that the State Museum must now address itself. In so doing, to effect the real educational purpose of this Museum, to bring into sympathetic play with the scientific purpose of the organization the natural interests of the people in the works of nature, to meet this enlarged opportunity for service, substantial aid must be afforded.

A half million citizens of this State visit the seat of government every year, some on business and some on pleasure, and the capital, among its other attractions, is now to present to them a public museum — the museum of the people themselves. It is needless to speculate as to what percentage of visitors will direct their footsteps to this place. It is not the purpose of the administration of the State Museum to offer to the visiting public a show of "curios," or a series of discrete and incongruous objects without rationale or consecuity. It is its purpose to bring through the public eye into the public heart the concerns of the natural resources of the State; the stories they tell, the business they record, the possibilities of commercial development they carry, the welfare and protection of the life that constitutes our native fauna and flora; to portray the development of the State from the beginning of its geography and with it to depict the course of its life through prehistoric stages up to the day of our aborigines with their multifold activities and culture; and so into the border lands of actual history.

Enough has been intimated in the foregoing in regard to the educational purpose of the State Museum of Science to make way for the conclusion that such functions can not be realized without a liberal support from an intelligent community. The State of New York can make what it will of its Museum — a storehouse of scientifically important but educationally arid facts, or a conservatory of inspiring and uplifting knowledge of its natural resources. To elect the latter as a deliberate policy of the Education Department is of necessity to supply the Education Department with the requisite funds to do it. It is in all respects a question of funds, for neither competent and enthusiastic men nor adequate materials are wanting for such an end.

It is therefore most proper at this juncture in the history of the organization to direct public attention to these requirements if the real purpose of the State Museum is to be assured.

Though it has been the practice of the State heretofore to encourage these several lines of scientific research, it has not been its practice to give hearty support to the development of its Museum. The State Museum as a depository of natural resources has been rather tolerated than espoused. Its collections have come to it incidental to other activities rather than purposely and for definite educational ends. The State Museum does not compete with the great civic but privately supported museums of this country and this day. Its field is not the world, but the State of New York. It should not attempt to exploit the world for its materials or for its educational purposes, but it should exploit the State of New York to its utmost, in order to set before the citizens of the State a conception of its natural resources and of the large scientific problems arising with them.

Conceding that its field is wisely restricted to the boundaries of the State, the State Museum should certainly have just as generous and substantial aid as is so freely given today to the private museum by the private patron. It is not enough for New York merely to recognize the fact that the State Museum exists simply because other states have created and recognize their museums. Nothing is enough for the proper pride of the State and its citizens except that this Museum shall be of the best and an effective arm of the educational service. It is not enough that the State Museum shall attempt to exercise its proper function with only the materials which may properly be designated as the accessories of its scientific researches. Nothing less than the best the State has is good enough for its people, and to permit this Museum to impart its instruction with less than the best, is to affront the people. The Museum of the people of this State should be of such quality as will bring credit to a State which has established a pioneer record for effective scientific research.

An illustration here is in point and immediate. The reportrayal of the life and culture of our aborigines, the Iroquois Confederacy, is one of the living functions of the Museum. In the Capitol fire a large part of the historic Indian collections were destroyed, some ten thousand specimens. The loss must be made good, so far as it is possible to do it. Time quickly wipes out records of the past. The Indian relics which were so common and perhaps so little valued in our boyhood are becoming scarce. The Iroquois Confederacy belonged to the State ot New York and is a momentous factor in its history; it stood between the French and English cultures on this continent and kept the United States and Canada from becoming colonies of France. Every relic of this ancient culture now left among the citizens or in the soil should become the property of the State and that too as quickly as possible. These relics are records as valuable as books, and the generations to follow us will justly pass condemnation if we allow them to pass into obscurity and forgetfulness.

Moreover the State Museum should be recognized as the State's single and proper depository of scientific natural objects. The people should understand that here is where they may come for all information upon the natural products of the State. It is bootless and confusing for the State to maintain a collection of scientific objects in Letchworth Park on the Genesee river, a few casefuls of birds and fishes in connection with one administrative department, and perchance of seeds and soils with another. Museums require today a high grade of technical service for the proper conservation of these materials. Such minor side efforts soon degenerate from lack of proper and intelligent care and involve an expenditure of public money for no good purpose.

Notwithstanding the support which has long been given to the work of the State Museum, its light has been too much under a bushel, it has had too much of the closet, has been too esoteric perhaps in its indifference to public appreciation. Its influence should reach to all the people. Yet it is well to record here the fact that a long and distinguished body of citizens have personally given their indorsement and support to its work; as witness the five hundred members of the New York State Museum Association, men of influence and distinction in all sections of the State.

III

CONDITION OF THE SCIENTIFIC COLLECTIONS

During the fiscal year some part of the usual field operations of the staff of the Science Division has been curtailed in order to meet the additional expense thrust upon the division by the operations preliminary to removal of the scientific materials to their new quarters. At the date of this report actual removal has not commenced but lies in the immediate future and the actual condition of the collections is now such that their transportation can be effected without delay or damage. Further than this, it has seemed wise to utilize the opportunity and some part of the available financial resources of the Museum to prepare and complete special objects and groups of objects of conspicuous worth and interest for prompt and ready display. These preliminary preparations have not been inexpensive. They have involved the dismembering and packing of large skeletons such as the whale, the mastodon, the elephant, the Irish elk and the entire series of lesser skeletons which could not be transported in their mounted condition. They have further involved the preparation of series of large models in plaster of especially noteworthy objects; and very particular packing of the State's extensive collection of birds and so on through the more delicate materials pertaining to the Museum. Provision has been made by the Legislature for the construction of cases for all the Museum collections on specifications which will make them of most modern type. This fine equipment will permit the Museum to leave behind it the antiquated and uninviting cases which pertain to its past career. The planning for this equipment has involved close and arduous study and has called for the continued attention of the members of the staff.

Notwithstanding these immediate internal duties of the division the lines of scientific research which properly pertain to it have been forwarded along their usual channels. The subjects which have engrossed the attention of the members of the staff have been somewhat diverse in character. The mineral springs at Saratoga have been the subject of close investigation as to their origin and an elaborate report thereupon has been issued. The study of the geographical development of the State has reached a point at which it has been possible to issue during the year a series of maps indicating the condition of New York at various stages during the period of retreat of the great ice sheet. The mineral industry of the State has received special attention and lines of possible future development of this industry have been indicated in the annual report on the mining and quarry industry. It is a part of the business of the State Geologist to execute a geological map of the State and this work has been in progress for a number of years, the base of the map being on a scale of one mile to the inch. This work has made a decided advance during the last year and the area of the State covered in this very great detail now approaches 20,000 square miles. Probably in no state has the plotting of its geology been carried on so minutely over so large an area. Of special interest also has been the work of the State Entomologist in his efforts to control the depredation of the many insect pests that are damaging the agricultural and native forest crops of the State. In this line this official has been very diligently occupied and with advantageous results.

IV

REPORT ON THE GEOLOGICAL SURVEY

AREAL GEOLOGY

In recent reports, statements have been made in regard to the progress of the areal mapping of the State on the topographic base map. During the past year, the additional quadrangles completed in western New York are those of Brockport, Hamlin, Albion and Oak Orchard. Preliminary control has also been made in the Medina and Ridgeway quadrangles. Reports with maps have been rendered in final form on the following quadrangles: Attica, Depew, Caledonia, Batavia, Eden, Silver Creek; the Phelps quadrangle is also essentially complete.

For this entire western New York region the present condition of the areal survey for the geologic map may be thus summarized:

Quadrangles published:

Auburn	Honeoye	Penn Yan
Buffalo	Naples	Portage
Canandaigua	Nunda	Tully
Elmira	Olean	Watkins
Genoa	Ontario Beach	Wayland
Hammondsport	Ovid	

Quadrangles reported:

Albion	Caledonia	Oak Orchard
Attica	Depew	Phelps
Batavia	Eden	Silver Creek
Brockport	Hamlin	

Quadrangles mapped:

Cherry Creek	Dunkirk	Westfield

Quadrangles begun:

Bath	Medina	Ridgeway

In northern New York a completed report on the North Creek quadrangle awaits publication. In the last field season, the Lake Pleasant quadrangle was surveyed by W. J. Miller, who reports that the prevailing rocks belong to the syenite-granite series and comprise syenite (augitic to hornblendic), granitic syenite, granite and porphyry. These rocks show all sorts of gradations from one type to another. Grenville gneisses, in areas sufficiently free from igneous rocks to permit separate mapping, are present in very subordinate amount. Grenville limestone is unusually scarce, only a few small outcrops having been noted.

Still other areas, often of considerable size, are made up of very closely involved syenite or granite and Grenville. Many times the evidence seems conclusive that Grenville gneisses have been melted and actually assimilated by the molten intrusions so that various rocks of intermediate character have resulted.

Only a few diabase and gabbro dikes have been found. Several of the diabase dikes are distinctly porphyritic with large plagioclase crystals, but the exact nature of these rocks has not yet been determined.

The chief geologic interest of the quadrangle centers about the valley at Wells because of the location there of the important outlier of Paleozoic rocks comprising Potsdam sandstone, Theresa passage beds, Little Falls dolomite, Black River (Lowville) limestone, Trenton limestone, and Canajoharie (Trenton) black shale. Altogether the thickness of these strata is about five hundred feet and their areal extent about three square miles. The valley is of the nature of a fault basin with distinct faults along the eastern and western sides and a minor one between. Along the western side of the outlier the displacement of the fault is no less than 2000 feet, the Canajoharie shales showing a decided updrag effect near the fault. A very careful survey of the vicinity of Wells has been made resulting in the first detailed areal map (with structure sections) of this the most interesting Paleozoic rock outlier in the Adirondacks.

Another feature of special interest is the discovery of an outlier of Paleozoic rock in the Sacandaga valley from one to two miles above Hope post office. The only strata visible are considerable ledges of Little Falls dolomite and a little of the Theresa passage beds and Black River limestone. These strata are sharply downfaulted at least 1200 feet against the steep mountain on the western side of the valley. A minor fault appears to bound this outlier on the east so that this too seems to be a fault basin.

The major topographic features of the quadrangle are largely determined by normal faults, most of which strike northeast-southwest, though certain important cross faults also occur. There are many good examples of fault blocks, ridges and basins.

Glacial striae show the movement of the great ice sheet to have been southward to southwestward. There are several fine examples of extinct glacial lakes, especially those in the valley at Wells; along the Sacandaga river between the mouth of the

West Branch and Northville; and in the valley of the West Branch in the vicinity of Whitehouse.

During the year we have issued a bulletin on the *Mineral Springs of Saratoga,* prepared by James F. Kemp, in connection with the series of investigations of the Saratoga district which have been in progress for several years. The region here concerned is covered by the Saratoga and Schuylerville quadrangles and the rock geology, especially intricate in the latter quadrangle, has now been finally mapped by Doctors Cushing and Ruedemann. Features of special importance in the Schuylerville region are the great overthrusts and overturned folds in the Bald mountain district and the problem presented by the Schuylerville volcanic plug penetrating the Paleozoic slates. The latter has been much debated. The shales about the volcanic mass have been distinctly overthrust and it seems very evident that the eruptive has been involved in this movement. There are reasons for regarding the plug as of Postpaleozoic age and as thrust by lateral shove many miles westward of its original position.

The investigation of the structure of the shale belt of the Schuylerville and Saratoga sheets has led to the inference that the mineral waters of Saratoga fill a wide basin below the shale formed by the Potsdam sandstone and overlying Cambric and Ordovicic limestones and that the water of the Saratoga springs is derived by filtration through mountain folds about the Hudson river and carried westward under the thick cover of the Canajoharie shales to the Saratoga-Mount McGregor fault and its branches, where it finds the thinnest cover of shale and thus escapes. The Canajoharie shale rapidly thickens southward on account of its dip, and the projecting fault blocks of Precambric rocks close the basin to the northward.

Outside of this immediate region, the work in the shale belt has further brought out the fact that the thick formation of the Normanskill shale comprises two divisions, a lower one corresponding to the Chazy, and an upper, corresponding to the Lowville–Black river interval. Normanskill shale graptolites were found in shale intercalated in the grit beds extending many miles along the Hudson about Hyde Park, N. Y., indicating that the shale belt there may be largely of Normanskill age. The broad belt of rocks extending from Schodack Landing to Stockport has hitherto been entered as Georgian on the State map, but the larger middle part of this is now known to consist of Deepkill shales, such characteristic graptolites as Didymograptus nitidus and Goniograptus thureaui having been found in railroad cuts below Stuyvesant.

In southeastern New York the complex problems involved in the *Tarrytown* quadrangle have received attention from Dr Charles P. Berkey who has been aided in his interpretations by his extensive knowledge of the underground rock structure in the course of the Catskill aqueduct.

The *Clove* quadrangle involving an area of Precambric and highly altered Paleozoic rocks east of Poughkeepsie has been studied by Prof. C. E. Gordon and for the most part mapped. The gneisses of the Highlands extend northward as a huge spur in the southeastern part of the quadrangle, and on the west and northwest are overlain by and faulted with the lower Cambric quartzite which in turn is faulted with the Fishkill limestone. Both quartzite and limestone continue northeastward from the Poughkeepsie quadrangle and all three associated formations present essentially the same relations in both areas.

At Poughquag, in the town of Beekman, is the type locality of the basal quartzite of southeastern New York and while fossils have not yet been found in it, the structural relations clearly demonstrate its identity with the rock yielding Olenellus at Johnsville in the town of East Fishkill. The basal quartzite ends against the schist of West Pawling mountain about two miles northeast of Poughquag. Between Poughquag and this point, what appears to be the northern margin of the quartzite forms " Garden Hollow." The drift is very heavy along the northern margin of the Highland spur, forming an exceptionally fine drumlin topography near Stormville, Green Haven and Poughquag. Northeast of the last village, it greatly obscures the relationships of quartzite, limestone and schist.

The northern boundary of the Fishkill limestone followed east from the Poughkeepsie area for a short distance presents the same serrated character, a short toothlike spur appearing just north of Sylvan lake. It then continues as a long narrow tonguelike spur eight or ten miles north of Poughquag in the valley of Fishkill creek and forms what is known as the " Clove." In tracing the eastern boundary of the limestone with the schist, a fine example of coarse fault brecciation was noted a mile and a half north of the hamlet of Clove indicating the character of the contact.

On the east the gneissic spur is overlain by schist which west of Pawling forms what is known as " West Pawling mountain " and farther north between the " Clove " and the Dover valley forms " Chestnut ridge." This garnetiferous mica schist, at places showing well-developed crystals of cyanite, is regarded as the metamorphosed derivative of the " Hudson river " slates. West of the " Clove" it grades into grits, phyllites and slates.

At Whaley pond is a patch of limestone known as the " white ledge " which is quite isolated from any other limestone outcrops. It is overlain by a quartzite, very similar to the basal quartzite and while clearly lying against the gneiss at places, apparently grades upward into the schist and appears to be a member of that formation. The relations of gneiss and schist along the eastern margin of the spur are still obscure.

Extending from the southern to the northern boundary of the quadrangle through the townships of Patterson, Pawling and Dover is the Dover-Pawling limestone valley. This has been mapped as far north as Wingdale. The eastern and western margins of the valley are irregular and in many places show a confusion of schist and limestone patches of varying sizes in juxtaposition and in such further relation as to suggest that they are dismembered portions caused by disturbances from beneath. Two miles north of Pawling at " Corbin hill " is a large patch of gneiss which is believed to be an inlier of the Precambric rocks; a broken piece of the Precambric floor thrust up among the younger rocks. It is bounded on the east, south and west by limestone and on the north by schist, and the field relations, as thus far studied, favor the view that all the contracts are faulted. The northwestern slope of the hill is heavily drift-covered.

East of the Dover-Pawling valley, as far north as Wingdale, the schist rises as a high mass of passes eastward into Connecticut.

SURFICIAL GEOLOGY

In continuation of his previous observations, work was carried on by Prof. H. L. Fairchild in the Hudson-Champlain valley.

In the report for 1911 (Museum Bulletin 158, pages 32–35), the hypothetical glacial Lake Vermont of Woodworth (Museum Bulletin 84) was provisionally accepted, and some high level shore features about Covey hill and in the St Lawrence valley were correlated with it. Some yet higher beach phenomena were attributed to glacial waters held up to the level of the Altona spillways, and these waters were called Lake Emmons.

Further study of the problem led to serious doubt of the correctness of these views concerning the ancient waters of the Champlain valley, and specially of the nature of the so-called Vermont waters, and it became necessary to reexamine the phenomena.

Under the theory holding the Vermont waters as glacial the summit plane of the marine waters was thought to be represented by the top of the series of heavy cobble bars about Covey hill, with an altitude of 525 feet. The shore features above this level were attributed to glacial lake waters. This view was accepted by Professor Goldthwait, who was studying the marine plane in the lower St Lawrence valley for the Canadian Survey.

Several considerations, specially the amount of land uplift in the district indicated by the Iroquois outlets, induced the belief that the Covey hill cobble ridges did not represent the highest stand of the oceanic waters, and that the " Lake Vermont " features (about 650 feet at Covey hill) were also produced by sea-level waters. At the beginning of the summer's work in 1912 a field conference was held with Professor Goldthwait and the features on a part of the Mooers quadrangle were reviewed. The beach phenomena between the Covey hill bars and the Vermont plane are very weak in that district. The lack of definite shore features above the summit plane of the Covey hill bars, 525 feet, is in strong contrast with the heavy development below that plane. The results of the conference were unfavorable to the view that the land surface above the Covey hill plane had been slowly raised out of the sea-level waters, like the slopes below that plane.

Immediately following the conference an examination was made of the phenomena on the territory south of the Mooers quadrangle, the newly surveyed Dannemora quadrangle, taking advantage of an advance copy of the unpublished Dannemora sheet. A very unexpected and surprising display of shore features was discovered. It was found that south of the Mooers quadrangle the Covey hill shore features are almost wanting, being replaced in the vertical position by a deluge of sand. But ranging above the Covey hill plane is a remarkable development of beach and delta features, reaching up to 700 feet. The strongest display of the cobble bars represents the " Vermont " plane, here from 500 to 600 feet, and they extend practically throughout the whole length of the Dannemora quadrangle. It is evident that these beaches correlate with the Cobblestone hill bars and other detached features on the Mooers quadrangle that formerly were puzzling.

Being specially developed in the town of Peru these bars in the " Vermont " plane will be called in this report the Peru beaches. This shore exhibits all the characters which argue for the marine origin of the Covey hill beaches. Taken in connection with the features on the adjacent Mooers quadrangle they afford an excellent illustration of the lack of value of negative evidence in study of shore lines, and the error in judging confidently from a single district or a limited area.

The Peru (" Vermont ") shore phenomena are found to be well developed southward throughout the Champlain valley, on both sides of the valley, and to lie far above the Fort Edward divide. They have been mapped on the Vermont side at Burlington, Middlebury and Brandon. The plane declines from 700 feet on the international boundary to 660 feet at Cobblestone hill, 520 feet near Ticonderoga, 440 feet near Glens Falls, and 390 feet near Mechanicville. The slope of the plane is a little over two feet a mile. These beaches are not the highest or summit bars of the region but were formed after some uplifting of the land had taken place. Their strength suggests that they represent a relative pause or a slower rate in the land uplifting.

The highest well-developed bars found on the Dannemora quadrangle are 706 feet in height, and lie west of Peru village. Behind the highest shore features throughout the quadrangle lie glacial drainage channels, terminating in deltas. These channels and deltas definitely determine the height of the standing waters during the recession of the ice front. This altitude on the Dannemora quadrangle was over 700 feet.

Northward the summit plane of the Champlain waters during the time when the ice sheet was waning is represented by beaches at Shea's Lines, on the Canadian boundary, south of Covey Hill post office, at about 750 feet; and also by the series of good bars at Cannon Corners, with an altitude of 750 feet. Southward the summit of the standing water is shown in various localities and specially at Port Henry. In the Hudson valley it is well shown. It is found that many cities and villages on both sides of the valley are located on broad summit plains of deltas that were built in the marine waters that occupied the valley as the ice gave way. This water plane rises from zero in the vicinity of New York to at least 350 feet at Schenectady, or at the rate of 2.2 feet a mile.

The practical continuity and correspondence in level of the highest water plane on both sides of the Hudson-Champlain valley proves that the waters filled the entire breadth of the valley and that the shore phenomena are not the product of ice-border lakes. It also appears that the waters were not held up by any moraine dam or any barrier of land uplift.

Over the Fort Edward divide the waters were more than 300 feet deep, and all the phenomena in the Fort Edward-Schuylerville district are those of static waters, slowly lowering and terracing the copious detrital deposits on both sides of the valley. There is found no evidence of any glacial stream flow below the summit water plane.

As the ice front melted back the ocean followed it and flooded the valley. The waters were at first the Hudson inlet; later the Hudson-Champlain inlet; and finally the Hudson-Champlain strait.

The minimum amount of continental uplift on the Canadian boundary is approximately determined by the deformation of the Iroquois plane. In the former report (page 32) it was shown that if we assume the Covey gulf outlet of Lake Iroquois to have been no lower than the original Rome outlet, then the district must have been lifted at least 665 feet. This makes the Covey hill bars 140 feet below the marine summit. The total uplift must have been as much more than 665 feet as the gulf outlet was beneath the plane of the Rome outlet. The study of the high-level shore phenomena leads to the confident belief that the Covey hill district has been uplifted at least 750 feet since the ocean waters displaced the ice sheet. This would carry the gulf channel only 85 feet beneath the Rome outlet.

Summary. Heavy and conspicuous static water phenomena occur with practical continuity on both sides of the Hudson-Champlain valley from New York City to Canada, rising steadily from zero at New York to 750 feet at the north edge of the State. Above this plane the land is cut by glacial drainage. All the facts now known and the relationship of the beaches to the topography of the valley walls indicate that the waters were confluent with the ocean. The absence of marine fossils in the higher deposits is probably chiefly due to the freshening of the water in the narrow inlet and strait by the very copious glacial waters.

INDUSTRIAL GEOLOGY

General review. The work in industrial geology which is directed chiefly to the investigation and description of the State's mineral resources has been carried forward actively during the past year. The annual summary of the local mining field, prepared in the form of a report for the general guidance of those engaged in the industry or otherwise interested in its current progress, has been continued, and the latest issue brings the information down to the close of 1911. Besides complete production statistics, the report contains notes and short articles dealing with the present sources of supply of the valuable minerals and the more interesting features involved in their exploitations. In the year 1911, conditions on the whole were rather unfavorable to mining and quarry operations; very few branches were able to report progress in terms of increased output. The aggregate valuation of $31,573,111 for the crude products was less by about 10 per cent than the total returned in the preceding year. The iron mining industry showed the full effects of the depression, as it is always very responsive to economic changes. The clay-working and quarry industries, especially the departments engaged in the production of building materials, were likewise much depressed. The setback had no serious consequences so far as concerns the permanent welfare of the industries, and it is expected that the record for 1912 will show some improvement, if not material gains, in many branches.

Talc. A sketch of the talc deposits of St Lawrence county and the present status of their industrial development has been prepared to meet the public inquiry for information on the subject. Some interesting developments have taken place during the last year or two, and it is hoped that with the preparation of large-scale topographic maps, a work now in progress, the opportunity will soon be forthcoming for a comprehensive account of the geology and economic features of the district. Since commercial operations were started, a little over thirty years ago, the mines have contributed nearly a million and a half tons, all of which required mechanical preparation before shipment to market. There is no other district in this country where the mining and milling of talc is carried on on so large a scale. The occurrence of metallic ores, including zinc blende, pyrite and hematite, in close proximity with the talc and in the same geological surroundings, is a noteworthy feature which has only recently attracted attention. The ores form pockets and bands in limestones and schist with the characteristics of replacement deposits. In any case, they have undoubtedly been introduced in solution and precipitated in their present place after the upraising of the sediments represented by the wall rocks. It would appear probable from these and from other considerations which need not be entered upon here that there is a close genetic relation between the talc and the metallic minerals. This point is of some significance in regard to the probable extent of the talc deposits and renders a more detailed investigation of the field highly desirable.

Zinc. A brief visit to the zinc ore localities of St Lawrence county was made during the summer for the purpose of studying the occurrences and securing material for the collections. There has been much activity in prospecting within the district, but the recent developments have been restricted, as in the previous year, to the locality near Edwards. As the result of recent discoveries, it is known that zinc blende has a rather wide distribution in the section from Edwards to Sylvia lake, which is practically coextensive with the talc district. The economic importance of the deposits is scarcely to be estimated as yet, but the work on the single property that is under exploration, lends encouragement to the hope that a substantial industry may be developed. Some difficulty has been encountered in the mill treatment of the ore which contains more or less pyrite in intimate association with the blende, the two minerals occurring usually in finely divided intergrown particles.

Field observations show that the blende is found in crystalline limestones of the same belt that includes the talc and tremolite beds. The limestone belt is interrupted here and there by bands of rusty, quartzose schists, and by dark basic hornblende and biotite gneisses. The rusty schists are very certainly a part of the same sedimentary series representing probably old sandstones, while the hornblende and biotite gneisses also are believed to be derived from sediments of the nature of shales, though in places they may represent altered igneous intrusions of gabbroic nature. The gneisses and schists have been invaded by a red granitic rock, with pegmatitic phases, that is developed in dikes, bands and occasionally as bosses of some size. The granite is perhaps related to the great batholiths of that rock which are found in the interior of the Adirondacks. The gneisses have been so injected and soaked by the granite that in places they partake quite as much of igneous as of gneissic character, in fact, all gradations from the one rock to the other may be found.

The limestones and schists have a northeasterly strike and are upturned at a high angle. The limestones of this section carry abundant impurities, though elsewhere the same series may be nearly free from admixture. The principal foreign minerals are silicates, most commonly tremolite, serpentine and talc. They are either scattered in small aggregates, or they form nodules, bands and veinlike bodies of practically solid silicates. The limestones are magnesian and in the vicinity of the ore bodies show the effects of solution and decomposition by ground waters. The circulation of water has been facilitated apparently by the broken, shattered nature of the rock which has undergone severe compression and more or less differential movement. The process of dolomitization and silication has preceded for the most part the introduction of the ores, but it may have resulted from the same agency, that is by the transporting of silica and magnesia held in solution in meteoric or deep-seated waters.

The zinc blende occurs in lenses and bands and also as scattered particles within the limestone. The deposits have the appearance of replacement bodies rather than the fillings of open fissures or cavities. In most places, the borders of the richer bands are not sharply defined, but are in the nature of transition zones which shade off gradually into the limestone. The internal structures are not those characteristic of open-fissure fillings as there is no appearance of crustification or of drusy cavities lined with crystallized minerals. The compact granular nature of the ore furthermore suggests deposition at considerable depth and under pressure.

The recent development work at Edwards has disclosed some interesting features in regard to the deposition of the ores which are the subject of current study. The problem as to the derivation of the ores seems to be interrelated with the partial silication of the limestones which has led to the formation, in the first place, of tremolite. This mineral has changed over to talc, more or less completely, through normal weathering or, which appears more likely, as the result of decomposition brought about by the later stages of the underground circulations that deposited the ores. The serpentine in larger part, however, seems to have formed directly, that is deposited as such from solution and not originating as an alteration product of an anhydrous mineral. Some of the serpentine is certainly later than the metallic minerals, as shown by the veins and stripes of the colloidal variety which intersect the ore, There are rounded aggregates which may represent an earlier generation, perhaps derived from a silicate mineral of the pyroxene or hornblende family. The talc nodules are frequently bordered by veins of massive serpentine that appear to have resulted as a reaction from contact of the talc with iron-bearing solutions. The limestones at this place have undergone considerable disturbances from regional compression since the deposition of the ores, manifested by the brecciated and faulted condition of the deposits in certain places and the flowage of the limestones into the fractures so as to cement the broken and disjointed parts. The whole mineral association seems referable to the work of underground waters which in a period of long-continued circulation have introduced and deposited various ingredients. There is insufficient evidence, as yet, to connect the mineralization with igneous agencies, and if these have been a factor, they were no doubt connected with the granite invasion, the only intrusive that has any prominence in the district.

SEISMOLOGIC STATION

The year's records for the local seismologic station are given in the accompanying table in conformity with the plan previously used in reporting the data. The list, it may be noted, includes only such disturbances as set up prolonged and well-marked vibrational movements, usually differentiated into phases — such as are referable without much doubt to true tectonic shocks transmitted to the station from more or less remote origins. Of almost daily occurrence are brief or indistinct motions arising from various causes not wholly explained, but these have not been taken into account in the table.

The number of individual tracings of earthquakes obtained within the year ending September 30, 1912 was twelve, as compared with nine in the preceding period, and nineteen in the year 1909–10. This record seems to indicate a general falling off of late in seismic frequency, at least with respect to the heavier shocks which are recorded mainly at the Albany station. There have been at the same time few destructive disturbances; within the past year, none has transmitted vibrations that exceeded the capacity of the instrument for registration.

Since the station was established in March 1906, it has supplied data in regard to ninety-eight individual shocks. In view of the fact that the installation represents an early type, comparatively, the results may be considered quite satisfactory. They sufficiently demonstrate that the somewhat peculiar conditions existing in this vicinity, particularly with respect to the heavy mantle of glacial sands and clays which cover the bedrock, are not incompatible with such service. The instruments belong to the lighter pattern of the horizontal pendulums and are not capable of a magnifying ratio of more than ten to one in the average run. They possess, however, the requisite sensitiveness for recording legibly the tremors of all heavy or damaging quakes throughout the seismic zones of this and other countries. There are in the local files tracings from such widely separated origins as California, Valparaiso, Kingston, the Himalayan region, Turkestan, Messina, Mexico, Costa Rica, Iceland, northern Alaska and Turkey in Europe. The smaller distant quakes, as well as the very slight jars from nearby sources, appear to be beyond the capacity of the instruments to register.

The general care of the instruments during the year has been assumed by Mr R. W. Jones. With their increasing age, they have required more attention to maintain them in working order, especially on account of their liability to rust. The station is very damp during the summer months and then they have to be frequently dismantled and thoroughly cleaned. As yet, no provision has been made for their removal to new quarters, and their maintenance in their present place will entail added labor for the future. In case a new station should be equipped near the present location of the Museum, it would appear advisable to instal one of the newer types of seismographs for registration of the smaller quakes, along with the present instruments which are well adapted to the registration of macroseisms.

RECORD OF EARTHQUAKES AT ALBANY STATION, OCTOBER 1, 1911 TO SEPTEMBER 30, 1912

Standard time

DATE	Beginning preliminaries	Beginning principal part	Maximum	End	Maximum amplitude
1911	H M	H M	H M	H M	mm
December 16	2 20½ P. M.	2 36 P. M.	2 38 P. M.	3 30 P. M.	15
1912					
January 31	3 20 P. M.	3 35½ P. M.	3 36 P. M.	4 25 P. M.	10
March 11	....	5 38½ A. M.	5 39 A. M.	6 00 A. M.	3
May 6	2 06½ P. M.	2 19 P. M.	2 20½ P. M.	3 20 P. M.	7
May 22	9 50½ P. M.	10 18 P. M.	10 22 P. M.	11 00 P. M.	4
June 7	5 56½ A. M.	....	....	6 17 A. M.	¼
June 7	7 41 A. M.	....	....	8 35 A. M.	¼
June 7	1 40 P. M.	....	....	2 30 P. M.	1
June 8	2 46 A. M.	3 01¼ A. M.	3 05¼ A. M.	3 40 A. M.	10
June 10	11 15¼ A. M.	11 33¼ A. M.	11 38¼ A. M.	12 30 P. M.	8
June 12	7 49½ A. M.	....	7 59 A. M.	8 30 A. M.	½
July 8	4 57¼ P. M.	5 17¾ P. M.	5 18¼ P. M.	6 00 P. M.	8

December 16th. A clearly marked record of the earthquakes that shook the city of Mexico on this date. The phases are well differentiated and give a very close approximation of the distance to the source, about 3000 miles. The larger vibrations are exhibited on the north-south component. Although the record would indicate it to be one of the heaviest shocks of the year, it appears to have done little damage.

January 31st. A good tracing of the earthquake that was central near Valdez, Alaska, when it occurred at about 10.12 o'clock in the morning. The east-west component is the larger. The indicated distance to the source is about 3000 miles.

March 11th. The preliminary tremors are not shown on the record. The origin appears to have been relatively near, perhaps in the West Indies. The Harvard station estimated the distance at about 1000 miles.

May 6th. A second Mexican quake, felt in the city of Guadalajara. The record is fairly clear, but less strong than that of December 16th. The tremors traveled as far as Germany.

May 22d. The record of a long-distance microseism with a period of from 20 to 30 seconds. It is not clearly separated into phases. An earthquake was reported from the Hawaiian islands on this date.

June 7th. A series of probably related disturbances from a source between 3000 and 4000 miles away, but not definitely located. A volcanic outburst occurred in the Alaskan peninsula about this time.

June 8th. This probably marks the culmination of the series of shocks which began the preceding day. Besides the heavy disturbance, there were light tremors at intervals which were so broken up by interference as to permit no satisfactory readings. The more notable of these minor movements occurred between 4.10 and 4.30 a. m., 5.22 and 5.33 a. m., and 7.55 and 8.45 a. m.

June 10th. An untraced disturbance about 3500 miles away.

June 12th. Very faint record, apparently not connected with the tremors, felt in South Carolina and Georgia the same morning.

July 8th. A rather strong disturbance with the east-west wave motion more pronounced than the north-south. The estimated distance of the source is about 4000 miles. A heavy shock occurred at Fairbanks, Alaska, about this time.

PALEONTOLOGY

In the reports of several years past, reference has been made to the progress of a memoir on the fossil arachnids or Eurypterida of New York. The work has now been completed and issued. It is the summation of many years of labor in the acquisition and study of this interesting extinct group of animals, which, by virtue of their abundance and variety in the rocks of New York, form one of the very striking features of its paleontology. This memoir is presented in two volumes, one of text and one of plates, the pages numbering 628 and the plates 88. A conception of the contents of the memoir is conveyed by its table of contents:

Volume 1

Volume 2

In last year's report a brief notice was given of an extraordinary section of the Siluric rocks on the Bay of Chaleur, at Black Cape. Previous to this account, only very brief notice had been taken of this place in the geological reconnaissance of that region, but as this section proves to be one of the extraordinary developments of the Siluric system, attaining a thickness of deposition perhaps not elsewhere equaled, it seemed very desirable to have a more exact examination of it made. With the consent and substantial support of the director of the Geological Survey of Canada, C. A. Hartnagel of this staff was detailed to this work.

Black Cape lies on the north shore of the Bay of Chaleur, seventy miles east of Matapedia and directly east of the valleys of the Grand

and Little Cascapedia rivers. In the Siluric section the strata are nearly all calcareous with intercalations of red shale near the top. They stand at high angles to the horizon, usually dipping 60–80° s. e., but these dips vary somewhat, though without unconformities. The eroded edges of the strata are overlain elsewhere in the region by the red sands and conglomerates of the Bonaventure formation, and there are several considerable fissures in the Siluric limestones which are filled in with red sand derived from the overlying beds. All these occurrences indicate land exposure of the Siluric during all the early and middle Devonic time.

The base of the section at the west begins with greenish, highly nodular lime-shales, very compact and heavy bedded, weathering out into irregular and gnarled shapes. These alternate with more highly calcareous shales and compact limestones of red and ochreous tints. These compact limestones contain Stricklandinias of great size (S. gaspensis Billings) and in great number and with these are Spirifers of the S. radiatus-niagarensis type and occasional Whitfieldellas. Throughout the lower beds the rest of the fauna is largely of Stromatoporoids and corals which occur in enormous quantity and great diversity. There are Halysites of several species, having horizon values, Favosites and Alveolites of great size, Heliolites, Syringopora, Eridophyllum in extensive colonies, Zaphrentis and other cyathophylloids in considerable variety. Additional species in these lower beds are Calymmene, Chonetes, Atrypa reticularis (Siluric type), Tentaculites, cyclostomatous gastropods, etc.

At an elevation in the series of about 1500 feet, where the scraggy limestones continue, there is some indication of change in the fauna by the addition of brachiopods of the genus Camarotoechia, Rafinesquina, the cephalopods Orthoceras, Trochoceras, etc. From Howatson's (elevation on section, 1500 feet) on eastward the scraggy limestones continue as far as the breakwater. Then follows a heavy mass of sandy shale. This sedimentation continues sandy to near the end of the section which terminates at the volcanic mass forming Black cape, but toward the top the sands become interlaminated with thin beds of volcanic ash, with red and purplish shale and eventually calcareous and variegated beds succeed to these, becoming in places compact lime banks entirely constituted of the debris of fossils.

These sandstones and sandy shales are remarkably profuse in corals, some of the species being palpably unlike those of the lower beds. Beyond the volcanic mass known as Black cape, there are several noteworthy inclusions of the fossil-bearing limestones within the lava.

So far as at present indicated by the fossils, this section from base to top is of the age of the Niagara (exclusive of Clinton) or Rochester shale of the interior Siluric, though the assemblage will doubtless show a preponderance of Atlantic or European types which will bring it into more proper comparison with the Gulf sections at Arisaig and on Anticosti island. Its thickness is not less than 7000 feet and in this respect the section overpasses any Siluric section known in America.

V

REPORT OF THE STATE BOTANIST

The plants collected during the season of 1911 have been mounted on herbarium sheets and arranged in their proper places in the herbarium or placed in boxes and distributed as far as possible in their proper places. Lack of room has prevented the completion of this work, but it is expected that removal to the Education Building will soon obviate this difficulty.

Specimens of plants, indigenous and naturalized, for representation of the species in the State herbarium have been collected in the counties of Albany, Essex, Lewis, Livingston, Monroe, Steuben and Sullivan.

Specimens have been contributed that were collected in the counties of Albany, Chautauqua, Cattaraugus, Clinton, Columbia, Fulton, Hamilton, Herkimer, Monroe, New York, Oneida, Ontario, Onondaga, Orleans, Oswego, Rensselaer, Richmond, Schoharie, Suffolk, Tompkins, Ulster, Warren and Washington.

Specimens of extralimital species have been contributed that were collected in Canada, California, Connecticut, Cuba, District of Columbia, Indiana, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New Jersey, North Carolina, Ohio, Pennsylvania, Utah and Vermont.

The number of species of which specimens have been added to the herbarium is 278 of which 72 were not before represented therein. Of these, 11 are considered new or hitherto undescribed species.

The number of those who have contributed specimens of plants is 70. This list includes the names of those who sent specimens for identification only, if the specimens were of such character and condition as to make them desirable additions to the herbarium. The number of identifications made is 1859; the number of those for whom they were made, 136.

Two species of mushrooms have been tried for their edible qualities, and though neither can be considered first class in all respects, both have been found to be harmless and palatable and have been approved as edible. Colored figures of them have been prepared and descriptions have been written. These make the whole number of New York species and varieties of mushrooms now known to be edible 215.

A small but attractive looking mushroom was discovered growing among decaying pine leaves in Richmond county by W. H. Ballou. He found it to be very poisonous. It is therefore figured and described as a poisonous fungus.

Specimens of seven species of Crataegus or thorn bushes have been added to the herbarium. Of this genus of trees and shrubs, 218 New York species are now recognized. Prof. C. S. Sargent, the eminent crataegologist, has kindly prepared a synoptical key to our New York species. This was a most difficult and intricate piece of work which none but an expert in this peculiar branch of botany could well do. In this work he has laid an excellent foundation for the study of these interesting though often considered nearly worthless and annoying shrubs and trees. He has added to this descriptions of 25 new species of this genus.

PLANTS ADDED TO THE HERBARIUM

New to the herbarium

Achillea ptarmica *L.*
Amanita ovoidea *Bull.*
Anellaria separata (*L.*) *Karst.*
Aposphaeria fibriseda (*C. & E.*)
Artemisia carruthii *Wood*
A. dracunculoides Pursh
A. glauca *Poll.*
Arthonia quintaria *Nyl.*
A. radiata (*Pers.*) *Th. Fr.*
Betula alba *L.*
Bolbitius vitellinus (*Pers.*) *Fr.*
Boletus retipes *B. & C.*
Calosphaeria myricae (*C. & E.*) *E. & E.*
Calvatia rubroflava (*Cragin*) *Morg.*
Chrysothamnus pinifolius *Greene*
Clavaria grandis *Pk.*
C. vermicularis *Scop.*
Cladochytrium alismatis *Büsgen*
Collema crispum *Borr.*
Collybia murina *Batsch*
Coronopus procumbens *Gilibert*
Crataegus gracilis *S.*
C. harryi *S.*

Crataegus leptopoda *S.*
C. livingstoniana *S.*
C. macera *S.*
C. procera *S.*
Creonectria ochroleuca (*Schw.*) *Seav.*
Diaporthe castaneti *Nits.*
Diatrypella favacea (*Fr.*) *Ces. & DeNot.*
Didymella asterinoides (*E. & E.*) *Rehm*
Dothidea baccharidis *Cke.*
Escholtzia californica *Cham.*
Flammula graveolens *Pk.*
Helicopsis punctata *Pk.*
Heliomyces pruinosipes *Pk.*
Helminthosporium fuscum *Fckl.*
Hydnum laevigatum *Sw.*
H. subcrinale *Pk.*
Hygrophorus ruber *Pk.*
Inocybe radiata *Pk.*
Lenzites trabea (*Pers.*) *Fr.*
Leptonia euchlora (*Lasch.*) *Fr.*
Macrophoma juniperina *Pk.*
Malus glaucescens *S.*
Mycena flavifolia *Pk.*
M. splendidipes *Pk.*
Opegrapha herpetica *Ach.*
Penicillium hypomycetes *Sacc.*
Pestalozzia truncata *Lev.*
Phialea anomala *Pk.*
Phoma asclepiadea *E. & E.*
P. semiimmersa *Sacc.*
Phyllosticta mahoniaecola *Pass.*
P. rhoicola *E. & E.*
Placodium camptidium *Tuck.*
Pleurotus tessulatus (*Bull.*) *Fr.*
Polyporus dryadeus (*Pers.*) *Fr.*
Puccinia urticae (*Schum.*) *Lagerh.*
Riccardia sinuata (*Dicks.*) *Limpr.*
Russula ballouii *Pk.*
Septoria margaritaceae *Pk.*
Silene dichotoma *Ehrh.*
Tricholoma latum *Pk.*
T. piperatum *Pk.*
T. subpulverulentum (*Pers.*)
Urophlyctis major *Schroet.*
Vermicularia hysteriiformis *Pk.*
Verrucaria muralis *Ach.*
V. papularis *Fr.*
Vicia hirsuta (L.) *S. F. Gray.*
Zygodesmus avellanus *Sacc.*

VI

REPORT OF THE STATE ENTOMOLOGIST

The State Entomologist reports that the past season was noteworthy because of the superabundance of the common *apple tent caterpillar* in the Hudson and Mohawk valleys and on the borders of the Adirondacks. The pests were so numerous that most of the wild cherries on the roadside were defoliated and many orchards severely injured. There were records of local damage here and there by the allied *forest tent caterpillar;* in several sections extended tracts were stripped of foliage. There is at least a fair probability of this insect being more abundant another season and possibly causing serious injury locally. The *green maple worm,* so numerous last year, attracted no attention the past season.

Petroleum compounds as insecticides. Dead and dying trees in several Greene county orchards which had been sprayed the preceding autumn with a commercial preparation of petroleum, led the Entomologist to study carefully the cases and the behavior of the trees through the season. A comparison was also made between the condition of these trees and injury of earlier years following applications of petroleum. He was unable to note any material difference between the two and, furthermore, observed a marked restriction of the damage to trees or even portions of trees which had received the application. After a careful study of the various phases of the matter he was forced to conclude that a certain measure of risk attaches to the application of mineral oils or preparations of the same to trees in a dormant condition. This matter is discussed in detail in the Entomologist's report.

Fruit tree pests. The experiments conducted by the Entomologist during the last three years against the *codling moth* were continued in the orchard of Mr Thomas Albright, of New Baltimore, and very satisfactory returns obtained. The check or unsprayed tree produced only 38.95 per cent of sound fruit, while sprayed trees of the same variety, less than 100 feet away, yielded over 97 and in some instances more than 98 per cent of worm-free apples. The results of this experiment and those of earlier years were checked by a careful study of representative trees in the orchards of Messrs W. H. Hart, of Poughkeepsie, and Edward Van Alstyne, of Kinderhook. These latter were sprayed under strictly commercial conditions with no expectation at that time of their being subjected to a test later. The results in these commercial orchards were very gratifying. The northern spies belonging to Mr Hart produced an average of over 98 per cent of sound fruit, while the greenings and Baldwins on the Van Alstyne place gave an average of over 96 per cent of worm-free apples. The past four years' experiments go far to show that under normal crop conditions one thorough and timely spraying for the codling moth should result in producing from 95 to 98 per cent of sound fruit. These tests are of great practical value to the fruit grower, since they afford a reliable basis for correctly estimating the value of spray applications.

The *pear thrips,* a minute insect which blasted or nearly destroyed the pear crop in a few orchards in the Hudson valley, was studied with special reference to conditions favoring injury, and the efficacy of spraying with a tobacco preparation demonstrated. The insect, potentially a very dangerous form, is discussed in the Entomologist's report. The work of the *pear midge* was investigated and a number of desirable photographs of the larva and its work secured.

Gipsy moth. The danger of injury by this notorious pest was emphasized by the discovery of a small colony, practically restricted to a city block, at Geneva. An examination of the locality showed that the infestation was probably of three or four years' standing. The chances are at least fair that the insect was introduced in that section with nursery stock, though no undoubted evidence as to the source of the infestation has been adduced. The discovery of similar colonies may be expected from time to time. For a period at least, no effort should be spared to exterminate such outlying infestations, since this policy is much cheaper and decidedly more advantageous to the general welfare than the adoption of repressive measures with the inevitable slow spread of the insect and the greatly increased cost of controlling the pest incident to its being distributed over an extended area. Such measures are also advisable, since checking the normal spread is most advantageous for the development of introduced parasites, a number of which have already been established in this country.

The recent enactment by Congress of a national plant quarantine act, recommended by the Entomologist and his associates in other states, is an important step in advance and should prove of great service in restricting the spread of this and other injurious insects as well as preventing the introduction of dangerous pests.

Brown-tail moth. This species has attracted comparatively little attention the past season, though owing to its having become established in the northwestern corner of Massachusetts, it is only a question of time before it will make its way into this State. The danger of this pest being introduced on nursery stock grown in infested sections still exists and should not be overlooked simply because a portion of the State is contiguous to infested territory. The winter nests are so characteristic that there should be little difficulty in identifying the insect and at the outset prevent its becoming excessively abundant.

Grass and grain pests. *White grubs* have been extremely numerous in portions of Albany, Columbia and Rensselaer counties, at least. They were so abundant in many places as practically to kill the grass over areas half an acre or more in extent. The roots were almost entirely destroyed and in many fields much of the sod was, as a consequence, torn loose where a horse rake was used. The outbreak was taken advantage of by the Entomologist to study in representative spots, the work of the grubs, their habits and natural enemies, with special reference to methods of control. A detailed account of his investigations is given elsewhere.

The *Hessian fly* caused serious losses in the wheat-growing section of western New York, destroying entire fields and, in many cases, reducing the yield by 50 per cent. An investigation of the injury was made for the purpose of ascertaining any peculiarities in its inception and determining the probabilities of serious damage another year. A number of parasites were reared from infested wheat stems collected in representative areas. An extended discussion of this insect is given in the Entomologist's report.

The *fall army worm,* another grass and grain pest, was excessively abundant in the vicinity of New York City, seriously injuring lawns, destroying millet and corn and feeding upon a variety of grasses. This outbreak was also investigated and a detailed account of the insect has been prepared.

Shade tree pests. The widespread and severe injuries of earlier years by the *elm leaf beetle* in the Hudson valley in particular, amply justified extended observations the past season. It was found that the exceptional damage in 1911 resulted in a feeble growth and weakened trees the past season. The early portion of the spring was unusually cool and moist and largely, as a result of these conditions, it is believed that injury by this pest was not so severe as last year. There was a marked irregularity in the work of the beetle, some trees in a locality and in certain cases some localities being almost exempt from injury, while in others the damage was relatively severe. A portion of this may be explained, possibly by more thorough spraying. Experiments were conducted with sweetened and unmodified arsenate of lead for the purpose of ascertaining if any material advantage was to be gained by the addition of a cheap sugar or molasses. There was no marked difference between the two series of tests and the earlier work with poisons was confirmed in large measure.

The *false maple scale* continues abundant in the vicinity of New York City and was a subject of considerable correspondence during the summer. The *cottony maple scale* was also responsible for a number of complaints.

Forest pests. The *hickory bark beetle* has continued its destructive operations in the vicinity of New York City. The abundance of this pest and the hearty cooperation of Mr J. James de Vyver, of Mount Vernon, made possible a series of tests for the purpose of finding some method which could be relied upon to destroy the insect after the beetles had entered the trees. Studies in the field showed that in some localities many of the grubs died within a few weeks after hatching and before they were able to cause material injury. A detailed discussion of this work, together with the Entomologist's investigations upon the biology of the pest and its natural checks, is given in his annual report.

Many of the white pines in the vicinity of Albany have been killed in recent years by *bark borers*. The Entomologist's study of the conditions showed that in all probability this attack was the outcome of extreme droughts and very low winter temperatures. Parties suffering from the activities of these pests have been advised to cut and burn all infested trees prior to the opening of another season.

Hosts of *Ambrosia beetles* belonging to the genus Platypus attacked freshly sawn, sappy mahogany in the yard of a veneer cutting company near New York City and inflicted severe loss besides causing grave apprehensions. An investigation showed that the insects originated from a shipload of mahogany from Panama. Upon the advice of the Entomologist, the infested material was removed and the few insects remaining soon disappeared.

The destructive work of the *locust leaf miner*, noticed in the Entomologist's report, was studied the past season and additional information secured in relation to its habits and methods of control. The most severe injury, as in 1911, resulted from the feeding of the beetles.

The *woolly bark louse* of the white pines has been the occasion of several complaints during the past summer, and an investigation showed that in some instances at least, large trees were seriously weakened if not destroyed by this insect.

A previously unknown though sparse colony of the periodical *Cicada* was located at Geneseo as an outcome of the interest aroused by the appearance of the enormous brood last year.

Flies and mosquitos. There has been a general interest in controlling the house fly and preventing the superabundance of mosquitos. Both of these insects have been the subject of correspondence, and a number of bulletins giving directions for remedying undesirable conditions have been distributed.

An unusual departure was the working out of the life history of a common blowfly, Phormia regina Meign. and a flesh fly, Sarcophaga georgina Wied., under controlled conditions. These two insects, though exceedingly common, were comparatively unknown except in a very general way. The details of this investigation, undertaken for the purpose of solving a specific problem, are given in the Entomologist's report.

Gall midges. This large group of small flies has continued to receive attention from the Entomologist. He has succeeded in identifying the wheat midge of Fitch, which proved to be an undescribed species, discovered and described a second form recorded as living in heads of American wheat, and reared another. The last was identified through the cooperation of European entomologists as Thecodiplosis mosellana Gehin. In addition, a number of new gall midges have been reared from various food plants and described. The outbreak by the *Hessian fly,* noted above, and an abundance of the *pear midge* in the vicinity of Albany afforded opportunity for additional studies of two economic forms.

Lectures. The Entomologist, as in past years, has delivered a number of lectures upon insects, mostly economic forms, before various agricultural and horticultural gatherings. This work enables him to become personally acquainted with the problems of various localities and has been greatly facilitated by a chart showing the results secured in the codling moth experiments of recent years.

Publications. A number of brief, popular accounts of the more injurious species of the year were widely circulated through the agricultural and local press. The more extensive publications, aside from the report for last year, are: *The Elm Leaf Beetle and the White Marked Tussock Moth* (Museum Bulletin 156), *Control of Insect Pests in Institutions, The Identity of the Better Known Midge Galls, The Fundamentals of Spraying* and several papers describing new species of gall midges. A list of the Entomologist's more important publications is given in his annual report.

Collections. There have been material additions to the collections through the efforts of the members of the office staff, and also by exchange and donation. Through the courtesy of Dr Otto Nüsslin of Karlsruhe, Germany, the Museum received an excellent series of European bark beetles. Mr Henry Bird, of Rye, generously donated an admirable lot of reared stem borers belonging to *Hydroecia* or closely allied genera, a number of these forms being almost unrepresented outside Mr Bird's exceptionally fine collection. The work of arranging and classifying the Museum collections has continued whenever opportunity offered. Considerable miscellaneous work has been done upon the beetles or Coleoptera, giving special attention to the flea beetles, Halticini of the Chrysomelidae and to the June beetles, Lachnosterna and its immediate allies of the Scarabaeidae. An excellent series of genitalic mounts was made in this latter group.

The value of the collections has been greatly increased by microscopic preparations. Specimens of the Scolytidae received from Doctor Nüsslin and noted above were put in balsam mounts. There were, in addition, two hundred such preparations of gall midges, mostly from reared material, and a number of scale insects, some previously unrepresented in the collections, which were similarly treated. The value of this material is much enhanced when placed in such preparations, since the latter are permanent in character and, in most of the species mounted, necessary for the identification of the insect.

The series of plant groups designed to serve as an embellishing and instructive feature of the enlarged exhibit now in preparation are practically completed. There has been special collecting for this exhibit.

The more ample facilities of the new quarters bring added responsibilities in the opportunity they offer of making the State collection of insects, both for exhibit and reference, thoroughly representative. The magnitude of such a task is appreciated by very few. The Entomologist recently assembled, with the cooperation of recognized authorities in various groups, the best obtainable figures as to the number of American insects. The data are tabulated below:

Hymenoptera	10000	Orthoptera	950
Coleoptera	11255	Neuroptera and Pseudoneuroptera	2000
Diptera	9100	Thysanoptera	118
Siphonotera	115	Other small orders	500
Lepidoptera	6622		
Hemiptera	3328		
			43988

A recent catalog of the insects of New Jersey, a state with a considerably smaller area and lacking the climatic and other diversities of New York, lists over 10,000 species. It seems conservative to place the probable number of insect species existing in this State at twice that figure. A thoroughly representative collection of New York forms should therefore contain well toward 20,000 native species, and since each has at least four well-marked stages, some 80,000 different forms. Many species and a great number of the stages are unknown. There is ample work to occupy a well-equipped corps of entomologists in the State Museum for many years, not to mention the much additional labor involved in assembling and maintaining greatly enlarged entomological exhibits.

Nursery inspection. The nursery inspection work conducted by the State Department of Agriculture has resulted in the Entomologist being requested to make numerous identifications and also recommendations in regard to the policy which should be pursued by the State. Many of the specimens submitted for name were in poor condition, and as they may represent any stage in insect development and frequently originate in a foreign country, such determinations are laborious and time-consuming. The correct identification of such material is, however, very important, since the disposition of large shipments of nursery stock must depend, in considerable measure, upon our findings.

Miscellaneous. In cooperation with the Division of Visual Instruction, the Entomologist secured an excellent and somewhat extended series of photographs, mostly of injurious or common insects. This material was all taken in connection with other collecting, it only being necessary to pose the specimen for the photographer.

VII

REPORT OF THE ZOOLOGIST

The time of the Zoologist and Taxidermist has been occupied chiefly in cleaning, repairing and packing the zoological collections for removal, especially those that were on exhibition in Geological Hall. As it was desired to keep the Museum open to the public as long as practicable, but few of these exhibits had been disturbed during the previous fiscal year, although the duplicate and study collections, with the exception of many of the shells, had been mostly packed. The shell collection was the most difficult to handle on account of the great number of specimens both on exhibition and in storage. As most of the shells were in uncovered paper trays, with loose labels laid upon them, it was important to pack them so that all chance of confusion would be avoided. This work occupied much of the time of the Zoologist and Taxidermist during the entire winter and part of the spring.

The bird and animal groups could not be packed, and it was decided to leave them as they were and have them carefully transported without packing. The single mounted birds and animals were, when not of too great size, packed in boxes by securing the stands to the bottom or sides of the box. When it seemed necessary, the specimen was given additional support to prevent shaking. Those too large to be dealt with in this way were wrapped in several thicknesses of tissue paper which was carefully tied on. In many cases, the specimens were cleaned and repaired previous to packing, but this was not always possible, on account of the large amount of material to be handled. This work had been largely completed by the end of the fiscal year.

The services of Mr C. E. Mirguet, formerly of Ward's Natural Science Establishment, and now in the employ of the United States National Museum at Washington, were obtained for taking apart and cleaning the skeletons of mammals and other vertebrates. The smaller ones were prepared for transportation without entirely disarticulating them, the skull, or the skull and limbs, being removed and packed so as to diminish the danger of breakage. The skeleton of the finback whale, which was hung by chains from the beams of the roof in the back wing of Geological Hall, was taken down, entirely taken apart and thoroughly cleaned by Mr Mirguet, and the skeletons of the other large mammals were similarly treated after disarticulating them as much as necessary.

Although the Museum has not been officially open to the public, people desiring to see the collections were not excluded from the exhibition rooms until the dismantling of the exhibits had progressed so far that too little remained to attract visitors, and the spaces in the exhibition rooms were required for the storage of the packed material.

MONOGRAPH OF THE NEW YORK MOLLUSCA

Dr H. A. Pilsbry's work upon the monograph of the New York Mollusca during the year has been directed chiefly to determining the generic characters of numerous forms hitherto inadequately known. To this end, considerable collecting has been done in the Hudson valley, Onondaga county and elsewhere to procure fresh, living material for description. Some forty-five figures of living mollusks have been drawn by the author, including, among others, representatives of the following genera:

Lyogyras	Planorbis	Zonitoides
Amnicola	Segmentina	Gastrodonta
Pomatiopsis	Physa	Helicodiscus
Valvata	Pupilla	Vallonia
Goniobasis	Bifidaria	Arion
Lioplax	Vitrea	etc., etc.
Lymnaea		

The external anatomy of part of these genera has hitherto been known in American works by figures of foreign species copied from European works, or by very crude figures and descriptions. The external soft parts of part of them have not before been figured or described. It is believed that the new facts brought out in the course of this work on American species are ample compensation for the time and labor spent thereon. Further work has been done on the descriptive part, and a large number of illustrations made, figuring all of the species which have been worked up. The completion of the monograph is expected next year (1913).

VIII

REPORT OF THE ARCHEOLOGIST

The work of the archeology section, as of all other sections of the Museum, has this year been modified to a considerable extent by the necessity of preparing to move its collections and office quarters into the Education Building.

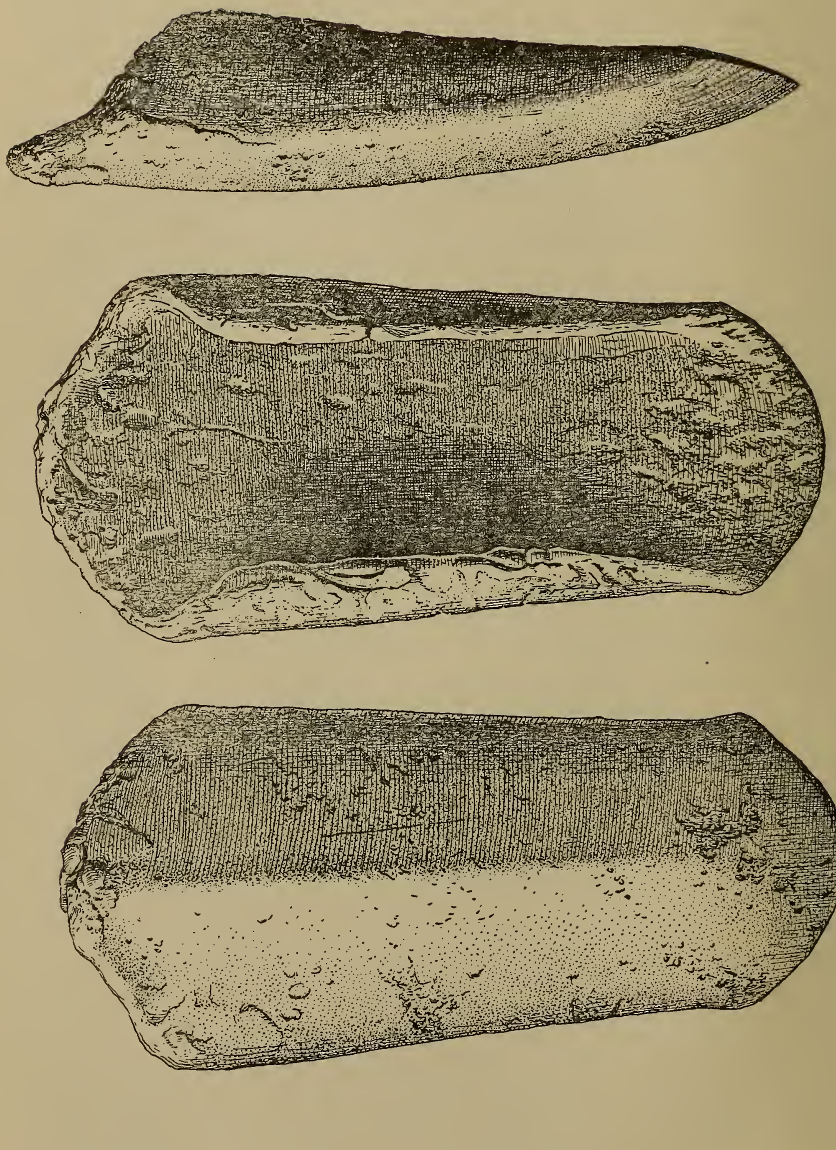
With the close of the fiscal year 1911 the Archeologist had about completed the preliminary work necessary for the exhibition of the Seneca Hunter group, in the ethnological series. A photograph of this group was reproduced in this report last year. With the assured success of the plan for this series of groups depicting Iroquois culture, steps were taken to complete all the preliminary work necessary for the plan.

The field painting of the Nichol's pond site was enlarged by Mr D. C. Lithgow, whose artistic ability and skill have been useful. This painting now complete is nearly fifty feet long and eighteen feet high and, like all others, is designed as a background for one of the groups. Further mention of this work will be made in the succeeding pages.

All the collections in the Archeologist's quarters in the Universalist Church building were packed and prepared for moving. It has therefore been impossible to make any further study of this material.

ARCHEOLOGICAL SURVEY

In cooperation with the United States Bureau of Ethnology, this section of the State Museum during the year has sent out several thousand requests for information concerning the sites and remains of former aboriginal occupancy. Reply envelops and blank forms for filling out were sent and about 75 per cent were returned with data filled in. In the majority of cases, these request forms had been sent to the presidents of local boards of education, to library presidents, to county clerks and to collectors, and thus to citizens who were familiar with the localities in which they lived. Several hundred new sites were added to the long list already in the possession of the Museum and will be properly tabulated. This information will not only be of the highest importance to the State Museum, but will form the body of the material used by the Bureau of Ethnology in its " Handbook of Aboriginal Sites and Remains."



Three views of a copper gouge from Canton, St Lawrence county

An attempt was also made to make a "census" of all the collections of aboriginal artifacts in the State and a new index has resulted, giving the lists of several hundred collections. In this manner, more than any other, an idea can be obtained of the localities most thickly populated in aboriginal times, but there is seemingly no correspondence between the abundance of earth works and the abundance of specimens. Large numbers of objects from all the various types and successions of occupancy are in the possession of individual collectors. The correspondence and indexing necessary to collect and file these statistics consumed a greater portion of the time up to May, but the knowledge gained is of practical as well as of high scientific importance.

In passing, it should be mentioned that many collections held by private individuals are neither numbered nor adequately cataloged. The collectors almost without exception remember where their objects were found, but without a permanent record the collection is robbed of its highest usefulness, and with the death of the owner, the otherwise valuable and instructive series becomes a mere aggregation of curiosities known as "Indian relics." In these days when the collection of such artifacts has a scientific object, every care should be taken to give each its precise locality. Topographical maps are of much use in this connection.

THE O. W. AURINGER COLLECTION

Supplementing in an important way the Dr A. W. Holden collection, donated last year by State Historian James A. Holden, is the Rev. O. W. Auringer collection, generously donated to the Museum by Dr Albert Vander Veer, of the Board of Regents. This collection is from about the same district as the Holden collection, that is Queensbury township and the region about Troy, north to Lake George.

An examination of the collection donated by Doctor Vander Veer reveals some important archeological facts which, supplemented by Mr Auringer's notes, give the collection a valuable place in our archives. The region from which the collection comes is characterized by several different occupations.

There have been unearthed on several Queensbury sites, flint knives and lance heads so old that the original flint — itself about the hardest of stones — had so far changed in substance as to have become chalky white in color, and in some cases so soft as to permit whittling with a sharp knife. Other objects have suffered surface changes from the original dull black of the stone to a lustrous yellow, or buff, or mottled color, according to the difference in soils in which they were imbedded. Such changes in the appearance and structure of flint can come only through exceedingly long and slow processes, and are occasioned by the percolation through soil of water charged with certain chemical elements, the effect upon the stone being the disintegration or final breaking down of one of the two kinds of silica of which it is composed.

The older artifacts occur mainly on a few extensive sites about the southern end of Lake George; at East Lake George; at Glen lake, and on a large site on the eastern town line about half way between Dunham's bay and the Hudson river at Sandy Hill. These sites, which Doctor Beauchamp calls "Early sites," are easily recognized by the initiated, on account of the remains they yield. Massive spear or lance heads, thick and heavy, yet in many cases almost as symmetrical and orderly in construction as if they had been wrought by machinery instead of by hand and eye; knives of flint and fine sandstone, thin and carefully wrought, leaf-shaped in form and edged all around, flaked by unground axes of sandstone and quartzite; acutely edged, finely shaped adzes and gouges of fine sandstone, of hollow and round-backed types; on the waterside sites large flaked disks of coarse sandstone, worked to an edge all around.

Following these traces of earlier men in Warren county, are the rather more broadly-sown of the two succeeding populations of different habits and instincts from their predecessors, and in these same respects also differing quite as much from each other. Our present knowledge in the matter does not definitely justify us in saying which was the earlier of the two, but their large and often curiously decorated pestles and mortars of stone show that they had a knowledge of agriculture. The Eskimo relics discovered point this people as once inhabiting our lands. For the sake of convenience only, we will turn our attention first to the traces of the first-mentioned people, in an endeavor to outline their habitat and realize something of their character and employments. They were agriculturists, huntsmen and fishermen, drawing from soil and forest and lake and river, their means of living. This signifies that they were a people of active energy; ambitious, resourceful, with an eye to the main chance — in short, in industrial affairs what the Mohawk was in war. They were inventive, with a decided instinct for art, shown in the decorative effects produced in the manufacture of their weapons and utensils. In their manipulation of stone, they were not satisfied with mere utility. They made an arrow or spear head an object of beauty to the eye, and manifested an accurate taste in the smoothness and symmetry of their pestles when any roughly-dressed stone would have served as well in a practical way. They were makers of pottery, small and large vessels of mingled clay and finely pounded stone, fire-baked and elaborately decorated, though in common with those preceding and following them, they were wholly ignorant of metallurgy.

Beginning at the oft-occupied settlement on the north bank of the Hudson river at the Big bend, we will endeavor to trace the lines of their residence to the northward to Glen lake, thence eastward into Washington county. Here at the rifts of the Hudson are found in the lower layers of soil, quantities of their pottery, celts, knives etc., while all to the north and northwest along Clendon brook and Meadow run, are yearly ploughed up their cylindrical pestles with an occasional mortar. Axes, knives, arrowheads and pottery are found in remarkable quantities. At the southern end of Glen lake, on the plateau where the Glen Lake hotel now stands, was a considerable village stretching thence to the elevated lands on the opposite bank of Meadow run, where that stream enters the lake. Following the western shore of the lake in our survey, we find few traces till we reach the outlet at Butternut flats. Here, on both banks of the creek, which at this point are much elevated, seems to have been an established town, with offshoots in various directions, first to the westward on the small brook near the Halfway house on the highway to Lake George. Then another northwestward, tucked for comfort up under the protection of French mountain, where a cold stream comes down from between the two spurs. Here the writer picked up, among various other objects, an arrowhead of pure transparent quartz crystal. These sites are identified by the fragments of early pottery which they yield. From Glen lake eastward the line of these old habitations follows the stream at intervals through to the Washington county line. Tradition refers to a stone-fortified village at Sanford's bridge, near Halfway brook, which, if tradition is correct, was evidently occupied by this people, since the frequent remains found in this neighborhood bear the stamp of their workmanship. A half mile to the eastward of this point, and under the high banks to the right of the Kingsbury road to Sanford's bridge, is a small site yielding large quantities of unworked flints. It would appear that these agriculturists worked the sand plains about the falls of the Hudson, as these two points are within the limits of the city of Glens Falls, which was inhabited; one on the site of the present French Catholic church, which has yielded large pestles, and another back of the city cemetery, and between it and Upper Glen street, producing various flints. That these early inhabitants were frequent visitors at Lake George in quest of game, is evidenced by the location of several of their camps, notably one at the head of the lake and another at Dunham's bay. We could not rationally expect to find here samples of their farming activities, from the nature of the soil, nor do we. But the pottery is in evidence here, showing that, like their white successors, they appreciated the advantages of life and health, which lie in frequent more or less protracted fishing and hunting trips. These small sites — there must be many more of them along the shores and among the islands — were their camps.

Returning to our base as Glen lake, we find traces along the eastern shore; and branching near the head of the lake a line of population followed very nearly by the present line as far south as the neighborhood of De Long's brickyard. Spreading to the east and west, this takes in the famous Blind rock and Hunter's brook tracts with the immediately adjoining territory.

One of the very interesting local problems is the relation of the Eskimos to the region east of Canada and to the former inhabitants of the upper half of New York State — about the Great Lakes, the St Lawrence river and the adjacent smaller streams and lakes. The Eskimos of Point Barrow retain in present use a certain kind of blade or knife of slate, ground and finely polished, in length of three to eight inches, stemmed and usually barbed, sometimes thin and flat, with a narrow bevel to form the cutting edges, often more thick, beveled off from a central longitudinal ridge running the length of the blade. These tools are singular in that no other existing peoples use them, nor from what follows does it seem that any other people ever did use them. In the portion of Canada bordering the Great Lakes, and about the streams and lakes in the upper half of the Empire State, many tools of identical character are found in the soil, associated with other objects such as flint arrow points, chipped quartzite blades, and the peculiar form of chipped flint scraper in archeology known as the Eskimo scraper, from its identity with like tools in use by the Eskimo of the north at the present time. Dr William M. Beauchamp, whom we esteem the best authority in archeological matters relating to our State, has furnished an excellent study of these remains; and he seems unhesitating in his belief that at some period quite remote, the regions about and to the northward of us were the established homes of the tribes now inhabiting the far north, known as the Eskimos. The truth would appear to be, that this was their home at a remote period, when the climate retained considerably more of arctic severity than is known at present; and that, following the receding cold upon the gradual encroachment of warmer conditions, and the migration of the cold-loving animals upon which they subsisted, they tended gradually northward till they at length found in the utmost north the favorite conditions of their well-being. Their chief habitat in the town of Queensbury was about Glen lake. There, at the northern end, or outlet, was a large, permanently established town covering many acres, from which ran lines of habitation in various directions: first northward under the base of French mountain for a distance, then striking off to East Lake George, where, as we might expect, there was a large village; second, a shorter line, comprising three small sites, with its terminus at Lake Sunnyside. Here, on the abrupt hill on the west shore of the lake was one of their lake dwellings. In the collection from Queensbury just donated by Dr Albert Vander Veer, is a card of several specimens of the "polished slate knife," among which is one obtained from the Washburn farm at French mountain, about a mile from Glen lake. It is made from Kingsbury banded red and gray slate, the red predominating, is of lance-head form, seven inches in length, by about one inch in mean breadth, has a central longitudinal ridge on each surface, is acutely pointed, with sharp edges. The stem is notched and there are well-defined barbs. With one exception this is the finest object of its kind among the one hundred and odd specimens so far reported. Saratoga lake has furnished a few of these knives, and two specimens have been discovered at Marcy, in Oneida county. They are rather more common about Lake Ontario and the neighborhood of Oneida lake than on the two sites just named. Prof. D. F. Thompson of Troy obtained one from the Bolton shore of Lake George; and from Lake Champlain, as we might expect, come a few others. A single specimen, the largest, but also the rudest in point of finish yet reported, comes from the Maine lakes.

Exactly what took place here at the close of the period we have been considering we do not know. But, by means of the alphabet of relics, supplied by the superficial soil, we are able to spell out a period of great confusion. The country here seems to have been overrun from about every quarter, judging from the pattern and material, foreign to the locality, of relics scattered so profusely about our fields. Flint from Ohio and farther west; copper from Michigan; grooved axes and soapstone pottery from the Atlantic tract; opaque quartz, and even obsidian, from the south — all these meet and dispute for the notice of the archeologist on Queensbury ground. At Assembly point, on Lake George, is a site yielding beaten copper spear and arrowheads. In Mr Auringer's explorations, he found a large grooved and polished limestone axe from the often-occupied site in Harrisena; and in line of association, fragments of large steatite, or soapstone pottery, have been taken from a site southwest of Glens Falls by a local collector. This signifies the presence in the intermediate period of the New England Algonquins. On Harrisena site again are found broad, thin and symmetrical polished limestone celts of quite other origin than the axes. How long the season of confusion lasted, it is impossible to know.

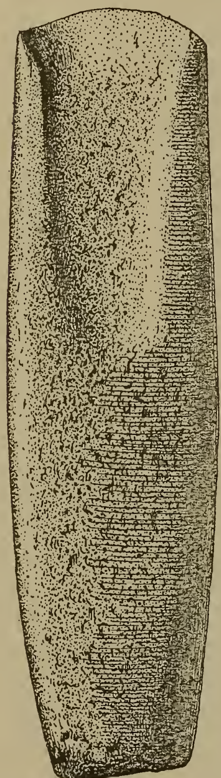
The territory including Queensbury was in the Algonquins' hands when the Europeans appeared on the scene. Having driven out the Iroquois, they ruled once more undisturbed in their ancient habitat. The Iroquois had gone down by two principal routes to the Mohawk valley, where they had already, prior to the advent of the whites, formed their powerful Confederacy. One of these routes was by the St Lawrence and Lake Ontario. The other was by the Champlain and Lake George trail to the Hudson river, and thence to the mouths of the Mohawk. It is possible to trace their line of migration from Dunham's bay southeastward to the county line and on to the Hudson at Hudson Falls. The first stage of this overland exodus is well marked by the remains of a considerable town situated on the flats bordering the inlet at Dunham's bay. From this point

Slate knives, probably of Eskimo origin from Glen lake, Saratoga county. Auringer-Vander Veer collection.

the trail ran southeasterly for some miles (a day's journey for an Indian) to a station on the county line road lying about the sources of Cold brook. Here the remains of occupancy are spread over many acres, and encroach upon and partly cover a permanent village site of the earliest inhabitants, whose remains have already been described. The relics of these two sites are exactly of the same character as those from Iroquoian stopping places on their westernmost route by way of the St Lawrence. They consist of fragments of the well-known clay pottery of the Mohawk tribes; pipes of red pottery; small triangular flint arrowheads; acutely edged celts and a few small flint knives.

A few years ago there was found on the site of the big bend a fine specimen of the steel "trade axe" with which the traders first armed their red neighbors. This is included in this collection and is in a fine state of preservation. There is also a fine and keen steel arrow and shaft, obtained from a site at the western base of Sugar Loaf mountain. Objects of copper have been found at the same place. A broken stone pipe drilled with steel tools of the white man comes from Glen lake. On the Bay road, on the farm owned by Elber Titus, was a Mohawk camp of late date. In addition to the small flint implements supplied by such stations, this field yielded one of the choicest objects of Mohawk manufacture which it has been my good fortune to record. It is a flat limestone pebble three inches in mean diameter, carved into the form of a young buck's antlers, and perforated at one side near the base for the purpose of suspension. Both surfaces are delicately carved into ridges, giving a corrugated appearance. It belongs to a class of objects termed personal ornaments. About Lake George and on many of its islands are frequent finds of Mohawk relics made. But the Mohawk never returned to occupy the country as a permanent residence. What we find of him here are but the remains of these temporary hunting or war camps, for he was often attracted this way from his home on the "Beautiful river," by the scent of game or scalps; but it was only as an intruder that he came.

In their manufacture of stone implements, the aborigines used such material as was found in their neighborhood. Where supplies of flint were lacking, they made use of native quartzite and even sandstone for their smaller weapons, as arrowheads, knives, and spear points, as well as for heavier tools. These native supplies they supplemented with flint in the block obtained by way of trade with neighbors occupying a flint-producing region. In Queensbury, we find the occupants of all periods using the local quartzite pebbles freely for long axes, celts, or hand axes, the larger class of spears and knives, and scrapers; while the local sandstones supplied the place of harder material for certain gouges and adzes. Laminae of fine sandstone served for the manufacture of finely wrought knives and lanceheads. The Eskimo worked the silex, or white flint deposit, on French mountain for material in the manufacture of large knives and spears, and even small arrowheads, while the neighboring slate quarries of Washington county served him in the matter of material for slate knives, ground and unground. And certain ceremonial stones, as the perforated gorget, bird and bar amulet, and often a banner stone, used by his predecessors, were of the same material. Many chisels and axes were made of the black limestone of the region, which was a favorite on account of the high polish it takes. Greenstone and conglomerate pebbles were utilized for celts and banner stones. At the foot of Glen lake was found a thick celt, or hand axe, of brown hematite, or ironstone. Hornstone and various flints often occur in limestone deposits; and doubtless the native miner understood the location of material of such value to him, in these eastern tracts. Nevertheless much flint in the rough must have been brought in from the western sources.[1]



Typical gouge from Warren county

ARCHEOLOGICAL COLLECTIONS

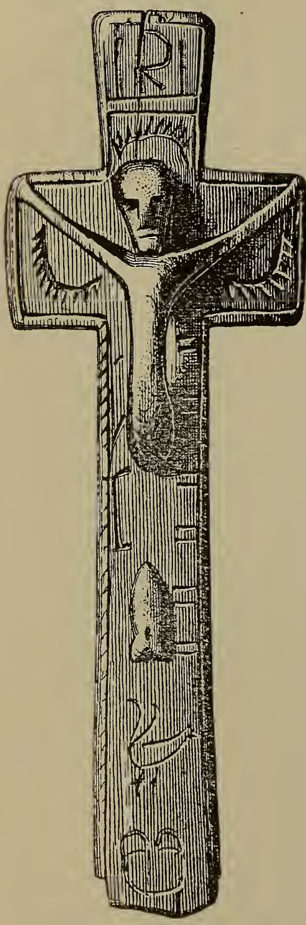
Among other interesting objects are a series of flints from Green Island and a semilunar or woman's knife from the mouth of the Hoosic river. This latter object was donated to the Museum by Mr Albert Hurd, of Troy, and represents one of the largest semilunars found in this region. It is a rare and valuable specimen and its donor is entitled to special thanks. A representation of this knife is shown in the accompanying figure.

[1] See N. Y. State Hist. Rept. by Auringer, 8: 102–12.

Semilunar knife from mouth of Hoosic river. Donated by Albert S. Hurd

An important mound was excavated during the year by Mr E. R. Burmaster, and a fine type of a mound skull obtained. This mound is in Chautauqua county and is one of the largest of its kind in the State.

A unique acquisition and addition to our collection of early religious objects is a crucifix obtained by Miss Pearl Hoppel in an old farmhouse at Fallsburg. It was evidently made by some Delaware or Minsi Indian in the early days and indeed has two totem animals of the Minsi carved upon it. The accompanying figure shows a representation of this object.



Crucifix probably carved by Minsi Indians. From Fallsburg, N. Y.

FOLKLORE

The study of the Iroquois rites and folklore was continued with much success. Valuable additions were made to the notes on the wampum codes and condolence ceremony. Mr Albert Cusick, long the helper of and coworker with Dr William M. Beauchamp, and previously the interpreter for Horatio Hall, was of much assistance in this connection. Mr Cusick is an Onondaga by birth and has long been regarded by the Onondagas, and indeed by all the Six Nations in New York, as their greatest authority on the council rites of the League of the Iroquois. In October, a few weeks after the Archeologist had completed his notes on tree symbols and myths, Mr Cusick died. This serves as a reminder of the fact that speedy work must be done if any amount of information is to be recorded. With the death of Chief John Gibson, of the Six Nations of Ontario, in October, another native annalist passed beyond reach. Mr Gibson had also been of considerable assistance to this section of the Museum.

With the corrections made by Chief Edward Cornplanter on the Code of Handsome Lake, the Seneca prophet, a manuscript version of the teachings of the celebrated Seneca chief, the manuscript was revised and with explanatory notes and appendixes, was submitted as a bulletin in the Museum archeological series. This work, now in press, will be a free translation of the religious belief of the modern nonchristian Iroquois of New York and Ontario, and should prove a work of some psychological as well as sociological and ethnological interest. It was Handsome Lake who revolutionized in sixteen years the disintegrating Seneca and Onondaga tribes and recrystalized their native beliefs. This was accomplished at a critical moment in the history of the Iroquois — immediately after the Revolutionary War, when the Iroquois League was broken and disheartened. Handsome Lake's teachings gave a new life and a new hope. The bulletin will be no. 16 in the archeological series.

PUBLIC INTEREST

Public interest in the work of the archeological section is attested by the large number of letters of inquiry which have come to this office and the many requests for information.

To museum authorities, especially, the plan for the ethnological groups has made an appeal, and a considerable number have visited the workshops for information as to methods.

IX

PUBLICATIONS

A list of the scientific publications issued during the year 1911–12, with those now in press and treatises ready for printing, is attached hereto. The publications issued cover the whole range of our scientific activities. They embrace 926 pages of text, 122 plates and 19 maps.

The labor of preparing this matter, verifying, editing and correcting is onerous and exacting. Taken altogether, it excellently indicates the activity and diligence of the staff of this division.

ANNUAL REPORT

1 Eighth Report of the Director, State Geologist and Paleontologist for the fiscal year ending September 30, 1911. 218p. 42 pl.

Contents:

BULLETINS

Geology

2 No. 153 Geology of the Broadalbin Quadrangle. By W. J. Miller. 1911. 66p. 8pl. 1 map.

Contents:

3 No. 154 Glacial Geology of the Schenectady Quadrangle. By James H. Stoller. 1911. 44p. 9pl. 1 map.

Contents:

4 No. 159 The Mineral Springs of Saratoga. By James F. Kemp. 80p. 3pl. 1912.

Contents:

5 No. 160 Glacial Waters in the Black and Mohawk Valleys. By H. L. Fairchild. 48p. 8pl. 17 maps.

Contents:

6 No. 161 Mining and Quarry Industry of New York. By D. H. Newland. 114p.

Contents:

Entomology

7 No. 155 Report of the State Entomologist for the fiscal year ending September 30, 1911. 182p. 35pl.

Contents:

8 No. 156 Elm Leaf Beetle and White-Marked Tussock Moth. By E. P. Felt. 35p. 8pl.

Contents:

Botany

9 No. 157 Report of the State Botanist for the fiscal year ending September 30, 1911. 139p. 9pl.

Contents:

GEOLOGIC MAPS

10 Broadalbin quadrangle
11 Schenectady quadrangle

In press

MEMOIRS

12 Birds of New York, volume 2
13 Eurypterida of New York

BULLETINS

Geology

14 The Geological History of New York State

Paleontology

15 The Lower Siluric Shales of the Mohawk Valley

Entomology

16 Report of the State Entomologist for the fiscal year ending September 30, 1912

Botany

17 Report of the State Botanist for the fiscal year ending September 30, 1912

Archeology

18 The Code of Handsome Lake, the Seneca Prophet

X

STAFF OF THE SCIENCE DIVISION AND STATE MUSEUM

The members of the staff, permanent and temporary, of this division as at present constituted are:

ADMINISTRATION

John M. Clarke, Director
Jacob Van Deloo, Director's clerk
Paul E. Reynolds, Stenographer

GEOLOGY AND PALEONTOLOGY

John M. Clarke, State Geologist and Paleontologist
David H. Newland, Assistant State Geologist
Rudolf Ruedemann, Assistant State Paleontologist
C. A. Hartnagel, Assistant in geology
Robert W. Jones, Assistant in economic geology
D. Dana Luther, Field geologist
Herbert P. Whitlock, Mineralogist
George S. Barkentin, Draftsman
H. C. Wardell, Preparator
Michael Sammon, Stenographer
Charles P. Heidenrich, Machinist
Joseph Bylancik, Page

Temporary experts

Areal geology

Prof. H. P. Cushing, Adelbert College
Prof. J. F. Kemp, Columbia University
Dr C. P. Berkey, Columbia University
G. H. Hudson, Plattsburg State Normal College
Prof. W. J. Miller, Hamilton College
Dr W. O. Crosby, Massachusetts Institute of Technology
Dr H. B. Kümmel, Trenton, N. J.

Geographic geology

Prof. Herman L. Fairchild, Rochester University

Paleontology

Edwin Kirk, Washington, D. C.

BOTANY

Charles H. Peck, State Botanist
Stewart H. Burnham, Assistant

ENTOMOLOGY

Ephraim P. Felt, State Entomologist
D. B. Young, Assistant State Entomologist
Fanny T. Hartman, Assistant
Anna M. Tolhurst, Stenographer
J. Shafer Bartlett, Clerk

ZOOLOGY

Willard G. Van Name, Zoologist
Arthur Paladin, Taxidermist

Temporary experts

Prof. E. Howard Eaton, Canandaigua
Dr H. A. Pilsbry, Philadelphia

ARCHEOLOGY

Arthur C. Parker, Archeologist

Temporary assistant

Howard A. Lansing, Albany

XI

ACCESSIONS

ECONOMIC AND GENERAL GEOLOGY

Collection

Newland, D. H. Albany

Building stones, rough and polished samples	25
Zinc and pyrite ores, St Lawrence county	20
Diabase dikes cutting granite, Dannemora, N. Y	3

Donation

Uniform Fibrous Talc Co. Talcville

Exhibit of crude and ground talc	10

PALEONTOLOGY

Donation

Eastman, Dr Charles R. Washington, D. C.
Plaster restorations of Bunodes, Pterichthys and Cladoselache 3

Landreth, William B. Deputy State Engineer, Albany
Mammoth tooth found while excavating for lock 26, on the barge canal, near Clyde, N. Y. 1

Van Horne, C. F. Glen
Concretions from Schoharie creek, at Glen (Montgomery co.) containing Utica slate fossils. 32

Exchange

Mathes, K. B. Batavia
Devonic fossils from various localities in Genesee county. . 125

Purchase

Plourde, Anthony. Migouasha West, P. Q.
Devonic fishes from Migouasha, P. Q. 120

Collection

Hartnagel, C. A.
Siluric fossils from Black Cape, P. Q. 1200

Ruedemann, R.
Fossils from Schuylerville sheet, Aries lake, Hyde Park, Schodack Landing 125

ENTOMOLOGY

Donation

Hymenoptera

Lewis, G. C. Lockport. Thalessa atrata Fabr., black long sting, adult, June 17

Dummett, Arthur. Mount Vernon. Apanteles congregatus Say, cocoons and adults, July 29

DeLong, E. W. Crown Point. Same as preceding, on Ampelophaga myron Cram., August 7

Mc Atee, W. L. Pickens, Miss. Cynips strobilana O. S., lobed oak gall, October 12. Also Neuroterus umbilicatus Bass., oak button gall on Quercus michauxii, October 12

Laney, C. C. Rochester. *Andricus seminator* Harr., wool sower, gall on white oak, June 21

Sherman, Miss Ruth H. Glens Falls. Same as preceding, June 24

Taylor, R. M. Ann Arbor, Mich. *Neuroterus saltatorius* Hy. Edw., galls on white oak, July 24

Blunt, Miss E. S. New Russia. *Cimbex americana* Leach, elm sawfly, larva on elm, September 20

Woodward, A. G. Through State Conservation Commission. *Tremex columba* Linn., pigeon tremex, adult, September 11

Brooks, E. C. Athens. *Caliroa cerasi* Linn., pear slug, larvae on pear, August 12

Robson, A. N. Lake George. *Kaliofenusa ulmi* Sund., elm leaf miner, larva on elm, June 13

Rutledge, Neil. Greenwich. Same as preceding, June 15

Devereaux, W. L. Syracuse. Same as preceding, June 19

Ward, J. G. Cambridge. Same as preceding, larvae and work on elm, June 24

Vail, Harry. New Mulford. *Trichiocampus viminalis* Fall., larvae, August 29

Coleoptera

Matheson, W. J. Huntington. *Eccoptogaster quadrispinosa* Say, hickory bark beetle, work on hickory, February 9

Merkel, H. W. New York City. Same as preceding, larvae and work, March 12 and June 17

Anderson, E. H. Scarsdale. Same as preceding, work, June 22

de Vyver, J. J. Mount Vernon. Same as preceding, adults and work, July 1

Dwyer, F. P. Yonkers. Same as preceding, work, July 30

Chapman, J. W. Dorchester, Boston, Mass. *Eccoptogaster multistriata* Marsh, imported elm bark borer, adults and larvae, October 5

Vitale, Ferruccio. New York City. *Pissodes strobi* Peck, white pine weevil, work on pine, July 11

Cunningham, Thomas. Vancouver, B. C. *Thricolepis simulator* Horn, gray, bark-eating weevil, adult on apple, May 2

Herrick, C. J. Elsmere. Pomphopoea sayi Lec., Say's blister beetle, adults on wild cherry, May 31

Hawley, G. H. Castleton. Coptocycla ? clavata Fabr., larva on morning glory, July 9

Gardner, M. H. Brewster. Galerucella luteola Müll., elm leaf beetle, adults, April 18

Crittenden, Mrs W. H. Cornwall. Same as preceding, May 10

Young, J. T. Watervliet. Same as preceding, eggs on elm, June 14

Gaskell, A. Ellenville. Same as preceding, adults, larvae and pupae on elm, July 11

Tate, L. A. Gloversville. Same as preceding, larvae and work on elm, July 16

Cook, W. M. Oyster Bay. Same as preceding, work on elm, August 5

Cunningham, Thomas. Vancouver, B. C. Glyptoscelis alternata Cr., leaf beetle, adult on apple, May 2

Rooney, J. O. Scarsdale. Elaphidion villosum Fabr., oak and maple pruner, larva and work on oak, July 24

Chatham Courier. Chatham. Monohammus confusor Kirby, sawyer, adult, July 10

Wend, Mrs George. Albany. Same as preceding, adult on pine, July 17

Bender, Matthew, jr. Niverville. Lachnosterna, June beetle, larva in grass sod, August 11

Woodward, W. M. North Chatham. Same as preceding, August 11

Moore, R. M. Rochester. Psephenus lecontei Lec., larva, September 25

Van Name, W. G. Albany. Dermestes vulpinus Fabr., leather beetle, all stages, March 26

Bernstein, Charles. Rome. Megilla maculata DeG., spotted lady-beetle, adults, December 13

Diptera

McAtee, W. L. Marksville, La. Thecodiplosis ananassi Riley, galls on Cypress, September 12

Dale, G. L. Mount Kisco. Caryomyia caryae O. S., gall on hickory, July 22

Rooney, Mrs J. O. Scarsdale. Same as preceding, July 24. Also Caryomyia persicoides Beutm.

Albright, Thomas. New Baltimore. Contarinia pyrivora Riley, pear midge, larvae on pear, May 27

Baker, C. F. Claremont, Cal. Asphondylia betheli Ckll., male, female, larva and pupa on Opuntia, April

Bethel, E. Denver, Col. Same as preceding, gall, male and female on Cactus, May 22

Rhines, W. D. Linlithgow. Simulium sp., blackfly, larvae, June 19

Bernstein, Charles. Rome. Eristalis tenax Linn., bee fly, larvae, August 27

Gillett, J. R. Kingston. Musca domestica Linn., housefly, larvae from cases of Myiasis interna, September 9

Amundsen, E. O. San Diego, Cal. ?Agromyza sp., adult on Wisteria buds, March 23

Lepidoptera

Principal, Schoharie High School. Schoharie. Through State Department of Agriculture. Polygonia ? comma Harr., hop merchant, eggs on hop, June 5

Delafield, Mrs I. D. F. Greenport. Euvanessa antiopa Linn., spiny elm caterpillar, larva on elm, June 25

Sweigert, J. A. Comstock. Same as preceding, July 1

Dodge, J. H. Rochester. Sphecodina abbotii Swain, larva on woodbine, July 10

Dummett, Arthur. Mount Vernon. Same as preceding, July 29

De Long, E. W. Crown Point. Ampelophaga myron Cram., grapevine hog caterpillar, larva on grape, August 7

Gaut, H. Glen Cove. Samia cecropia Linn., Cecropia moth, cocoon, December 28

Jackson, Mrs A. M. A. Warner. Telea polyphemus Cram., American silk worm, eggs, June 6

Wilbor, Miss M. R. Old Chatham. Callosamia promethea Dru., Promethea moth, cocoons, May 10

Martin, Mrs Martha W. Albany. Same as preceding, larvae on lilac, August 5

Worman, A. E. Fillmore. Through State Conservation Commission. Diacrisia virginica Fabr., Virginia ermine moth, adult, June 20

Strickland, L. F. Lockport. Through State Department of Agriculture. Arctia caja Linn., garden tiger moth or woolly bear of Europe, larva, October 26

Woolworth, C. C. Castleton. Alypia octomaculata Fabr., eight-spotted forester, larva on woodbine, July 10

Mostow, Robert. New York City. Laphygma frugiperda Sm. & Abb., fall army worm, larvae and pupae on lawn, September 11

Latham, Roy. Orient Point. Same as preceding, September 11

Parsons, Samuel. New York City. Same as preceding, September 11 and 21

Niles, T. F. Chatham. Agrotis ypsilon Rott., black cutworm, larva, June 10

Rogers, F. E. Oswego. Mamestra picta Harr., zebra caterpillar, larvae on pear, July 16

Bird, Henry. Rye. Papaipema appassionata Harvey, P. necopina Grt., P. frigida Sm., P. sciata Bird, P. inquaesita G. & R., P. maritima Bird, P. rigida Grt., P. marginidens Gn., P. moeseri Bird, P. duplicata Bird, P. cerussata Grt., P. duovata Bird and Apamea erepta var. graminea Bird, August 14

Bailey, G. W. Geneseo. Alabama argillacea Hübn., cotton moth, adults, October 9

Mosher, H. J. New Berlin. Same as preceding, October 11

Bishop, I. P. Buffalo. Same as preceding, October 13

Green, A. H. Shushan. Catocala sp., caterpillar, June 19

Richardson, M. T. New York City. Datana integerrima Grt. & Rob., black walnut worm, larvae on English walnut, August 5

Smith, C. H. Mohegan Lake. Same as preceding, caterpillars, August 22

Wiltse, J. W. North Chatham. Schizura concinna Sm. & Abb., red-humped apple caterpillar, larvae on apple, July 9

Dodge, J. H. Rochester. Tolype laricis Fitch, larch lappet moth, larva, August 8

Coventry, T. L. Utica. Malacosoma americana Fabr., apple tent caterpillar, larvae, June 12

Matthews, P. B. Bridgehampton. Through State Department of Agriculture. Same as preceding, larvae on oak, June 19

Whitcomb of The Commonweal. Greenwich. Same as preceding, adult, July 7

Chahoon, George. Ausable Forks. Same as preceding, cocoons, July 13

Hicks, Isaac & Son. Westbury. Malacosoma disstria Hübn., forest tent caterpillar, larvae, June 10

Worman, A. E. Fillmore. Through State Conservation Commission. Same as preceding, larvae, June 20

Vosburgh, G. C. Moravia. Eranis tiliaria Harr., basswood inch worm, larvae on elm and basswood, June 8

Brown, Miss Helen A. Brooklyn. Thyridopteryx ephemeraeformis Haw., bagworm, larvae on purple beech, August 2

Felten, G. R. Cementon. Sibine stimulea Clem., saddleback caterpillar, September 3

Mulholland, J. B. Kingston. Same as preceding, larvae on blackberry, September 24

Hicks, Isaac & Son. Westbury. Zeuzera pyrina Linn., leopard moth, work on hickory, October 26

Mulligan, E. T. New York City. Through State Department of Agriculture. Same as preceding, larva, December 24 and 27

Lobdell, Miss Mary L. Woodhaven. Same as preceding, larva, March 17

St John, C. L. Canajoharie. Mineola indigenella Zell., leaf crumpler, larval cases, February 24

Stevens, Ogden. Albany. Ephestia cautella ? Walk., larvae and adults on English walnuts, November 20

Smith, W. F. Valhalla. Evetria ? frustrana Comst., caterpillar on pine, August 30

Fernald, H. T. Amherst, Mass. Evetria ? comstockiana Fernald, pitch twig moth on pine, June 12

Scofield, R. Coeymans. Tmetocera ocellana Schiff., bud moth, larvae in pear buds, May 8

Emmons, G. E. Schenectady. Tortrix fumiferana Clem., spruce bud moth, larvae on spruce, June 3

Weld, F. M. New York City. Coleophora caryaefoliella Clem., larvae and work on hickory, July 13

Evans, Cadwallader. Stellarton, Nova Scotia. Bucculatrix canadensisella Cham., birch leaf skeletonizer, molting cocoons, August 29. Also larvae, cocoons and work on birch, September 18

Harrison, David. Staatsburgh. Phyllonoryter hamadryella Clem., oak blotch leaf miner, mines on oak, July 29

Wier, Miss Anne R. Garrison. Same as preceding, work on oak August 5

Clark's Sons, D. Fordam Heights, New York City. Through State Department of Agriculture. Gracilaria near violacella Busck, larvae on azalea, March 7

Neuroptera

Nixon, I. L. Rochester. Corydalis cornuta Linn., horned Corydalis, adult, July 1

Thysanoptera

Ward, G. E. Ravena. Euthrips pyri Dru., pear thrips, adults on apple, May 1

Hemiptera

Bailey, G. A. Geneseo. Tibicen septendecim Linn., seventeen-year Cicada, adult and pupal case, June 14

Dodge, J. H. Rochester. Cicada ? linnei Grossb., harvest fly, adult, August 26

Buchholz, A. B. Geneva. Through State Department of Agriculture. Phylloxera caryaecaulis Fitch, hickory gall aphid, old galls on hickory, October 26

Armer, H. N. Ballston Spa. Through State Conservation Commission. Chermes pinicorticis Fitch, pine bark aphid, adults on pine, July 5

Judson, W. P. Broadalbin. Same as preceding, July 12

Duhamel, M. F. Poughkeepsie. Same as preceding, August 8

Baker, A. M. Oneonta. Hormaphis hamamelidis Fitch, witch-hazel cone gall, galls on witch-hazel, August 5

Banks, Mrs R. S. Albany. Pemphigus populi-transversus Riley, gall and young on poplar, June 18

Olsen, C. E. Maspeth, L. I. Schizoneura americana Riley, woolly elm leaf aphis, young on elm, June 18

Hareford, Miss Alice C. Watertown. Same as preceding, adults and young on elm, June 21

Fuller, A. R. Malone. Same as preceding, adults and work on elm, July 18

Niles, Mrs S. H. Coeymans. Schizoneura lanigera Hausm., woolly apple aphis, young on apple, November 8

Delehanty, J. A. Albany. Same as preceding, nymph on apple, August 26

Marshall, D. T. Hollis. Chaitophorus aceris Linn., work and young on Norway maple, July 6

Gibson, W. W. Watervliet. Same as preceding, nymphs on Norway maple, July 11

Waterman, R. S. Ogdensburg. Callipterus ulmifolii Mon., elm leaf aphis, adults on elm, July 1

Barrus, G. L. Paul Smiths. Mindarus abietinus Koch., work on balsam, July 1

Latham, Roy. Orient Point. Aphis nasturtii Kalt., adults and nymphs on nasturtium, October 3

Brock, J. G. Binghamton. Gossyparia spuria Mod., elm bark louse, males and females on elm, May 29

Cockerell, T. D. A. Boulder, Col. Eriococcus borealis Ckll., adults, October 7

Hessberg, Samuel. Albany. Phenacoccus acericola King, false maple scale, males on maple, June 11

Cockerell, T. D. A. Glenwood Springs, Col. Trionymus violascens Ckll. (part of type), adult on Agropyron, October 2

Olsen, C. E. Maspeth. Pseudococcus citri Risso, mealy bug, adult, July 20

Marshall, D. T. Hollis. Pulvinaria vitis Linn., cottony maple scale, adults and young on soft maple, July 6

Tioga county. Through State Department of Agriculture. Lecanium sp., Lecanium scale, adult and young on Tecoma radicans, November 1

Carpenter, E. E. Morris. Same as preceding, adults on oak and chestnut, June 8

Woodlawn Cemetery. New York City. Through State Conservation Commission. Asterolecanium variolosum Ratz., golden oak scale, adult, June 14

Livingston, J. H. Tivoli. Toumeyella liriodendri Gmel., tulip tree scale, young on tulip tree, February 12

Harris, A. G. North Pelham. Same as preceding, adults on tulip, July 29

Thomson, Miss Annis E. Yonkers. Same as preceding, July 29

Clark, S. M. Warrensburg. Eulecanium ? canadense Ckll., adults on elm, May 27

Van Aken, Silvanus. Port Ewen. Eulecanium ? persicae Fabr., peach scale, adults and eggs on crimson rambler rose, June 17

Lown, Mrs Robert. Idlewild. Same as preceding, July 2

Heavey, J. Buffalo. Chionaspis furfura Fitch, scurfy scale, eggs, March 5

Levison, J. J. Brooklyn. Chionaspis americana Johns., elm scurfy scale, egg on elm, February 6. Also Chionaspis pinifoliae Fitch, pine leaf scale, egg on Austrian pine, February 6

Duff, Mrs Harriet A. Kinderhook. Chionaspis pinifoliae Fitch, adults on pine, September 16

Through State Department of Agriculture. Rochester. Diaspis carueli Targ.-Tozz., juniper scale on juniper, May 16

Heavey, J. Buffalo. Aspidiotus perniciosus Comst., San José scale, young, March 5

Williams, C. L. Glens Falls. Same as preceding, May 24

Stone, D. D. Oswego. Aspidiotus ancylus Putn., Putnam's scale, half grown, April 19

Latham, Roy. Orient Point. Chrysomphalus aonidum Linn., rubber scale insect, adults on rubber plant, April 22

Gaut, H. Glen Cove. Lepidosaphes ulmi Linn., oyster shell scale, egg on willow, December 28

Heavey, J. Buffalo. Same as preceding, eggs, March 5

Henkes, Fred. Watervliet. Through State Department of Agriculture. Same as preceding, old scales on apple, May 11

Hasbrouck, Levi. Ogdensburg. Same as preceding, June 22

Olsen, C. E. Maspeth. Same as preceding, adults on white birch, July 20

Through State Department of Agriculture. Schenectady. Parlatoria theae Ckll., adult on Japanese maple, April 25

Overton, Miss Lillian C. Albany. Haematopinus piliferus Burm., sucking dog louse, adults on dog, April 8

St John, C. L. Canajoharie. Blissus leucopterus Say, chinch bug, adults and young, September 26

Buchman, Edwin. Valley Falls. Acholla multispinosa DeG., spined assassin bug, nymph, August 13

Briggs, G. J. Macedon. Cimex lectularius Linn., bedbug, adult, May 12

Williams, C. L. Glens Falls. Lygus pratensis Linn., tarnished plant bug, work on dahlia, July 17

Strickland, L. F. Lockport. Poecilocapsus lineatus Fabr., four-lined leaf bug, adults on currant, June 19

Latham, Roy. Orient Point. Benacus griseus Say, giant water bug, adult, June 10

Orthoptera

Dummett, Arthur. Mount Vernon. Diapheromera femorata Say, walking-stick, adult, August 20

Thysanura

Stagg, J. E. Buffalo. Through State Department of Agriculture. Lepisma domestica Packard, silver fish, adult, October 25

Acarina

Osterhout, G. E. Windsor, Col. Eriophyes pruni Schoene, plum mite, galls on plum, July 22

Herrick, G. W. Ithaca. Phyllocoptes quadripes Shimer, bladder maple gall, galls on soft maple, June 11

Babcock, H. N. Elmira. Same as preceding, June 24

ZOOLOGY

Donation

Mammals

Paine, Silas H. Silver Bay

Red squirrel, Sciurus hudsonicus (Erxleben).....	3

Birds

Rensselaer Polytechnic Institute, Troy

Dowitcher, Macrorhamphus griseus (Gmelin)	1
Hudsonian godwit, Limosa haemastica (Linnaeus)	1
Sharp-shinned hawk, Accipiter velox (Wilson)....	1
Pigeon hawk, Falco columbarius (Linnaeus)..	1
Ivory-billed woodpecker, Campephilus principalis (Linnaeus)	1
Prairie hen, Tympanuchus americanus (Reich.).	1

Sanford, Dr Leonard S. New Haven, Conn.

Old squaw, Harelda hyemalis....................	1

Birds' nests

Delavan, Dr C. H. Round Lake

Baltimore oriole, Icterus galbula (Linnaeus)......	1
Red-eyed vireo, Vireosylva olivacea (Linnaeus).	1

Fishes

Bean, Dr Tarleton H. Albany

Dace, Semotilus bullaris (Rafinesque).........	1

Invertebrates

Casselman, E. S. Lake Delaware
Copepods, Cyclops strenuus Fischer............ 1 lot
Peck, H. S. Menands
Spider, Lycosa carolinensis, Walckenaer, female and eggs.................................. 1
Cass, Allan. Albany
Slug, Limax maximus, Linnaeus.................. 1
Bean, Dr Tarleton H. Albany
Fresh-water clams, Unionidae.......................... 2 lots

Exchange

Fresh-water and land shells

Baker, H. B. Ann Arbor, Mich.
Goniobasis livescens (Merke)
Campeloma decisum (Say)
Valvata sincera (Say)
Amnicola limosa (Say)
Vitrea ferrea (Morse)
Cochlicopa lubrica (Müller)
Strobilops virgo (Pilsbry)
Succinea retusa (Lea)
Lymnaea emarginata (Say)
Lymnaea emarginata angulata (Sowerby)
Lymnaea stagnalis appressa (Say)
Lymnaea stagnalis perampla (Walker)
Physa ancillaria magnalacustris (Walker)
Physa ancillaria parkeri (Currier)
Aplexa hypnorum (Linnaeus)
Planorbis hirsutus (Gould)
Planorbis bicarinatus portagensis (Baker)
Planorbis campanulatus smithii (Baker)
Planorbis bicarinatus (Say)
Segmentina crassilabris (Walker)
Sphaerium sulcatum (Lamarck)
Sphaerium acuminatum (Prime)
Pisidium abditum (Haldeman)
Pisidium abditum subrotundum (Sterki)
Pisidium regulare (Prime)
Lampsilis luteola (Lamarck)
Lampsilis nasuta (Say)

Anodonta grandis footiana (Lea)
Anodontoides l'erussaciana subcylindricacea (Lea)

Purchase

Mammals

Barker, Fred. Parker's Prairie, Minn.
Weasel, Mustela cicognani (Bonaparte 1
Mole, Scalopus aquaticus (Linnaeus) 1
Ward's Natural Science Establishment, Rochester
Common dolphin, Delphinus delphis Linnaeus, cast 1

Birds

Barker, Fred. Parker's Prairie, Minn.
Holboell grebe, Colymbus holboelli (Reinhardt) .. 1
Ring-billed gull, Larus delawarensis Ord 2
Bonaparte gull, Larus philadelphia (Ord) 1
Common tern, Sterna hirundo Linnaeus 3
Black tern, Hydrochelidon nigra surinamensis (Gmelin) 2
White pelican, Pelecanus erythrorhynchos Gmelin 1
Virginia rail, Rallus virginianus Linnaeus 2
Stilt sandpiper, Micropalma himantopus (Bonaparte) 1
Semipalmated sandpiper, Ereunetes pusillus (Linnaeus) 2
Lesser yellowlegs, Totanus flavipes (Gmelin) 2
Black-breasted plover, Squatarola squatarola (Linnaeus) 3
Killdeer plover, Oxyechus vociferus (Linnaeus). 2
Ring-necked plover, Aegialitis semipalmata (Bonaparte) 2
Brown, Wilbur. Albany.
Barred owl, Strix varia Barton 1
Danygriz, Mathew. Albany
Sora, Porzana carolina (Linnaeus) 1
Yellow rail, Coturnicops noveboracensis (Gmelin) 1
Wilson phalarope, Steganopus tricolor (Vieillot). 1

Avocet, Recurvirostra americana Gmelin...... 1
Stilt sandpiper, Micropalma himantopus (Bonaparte) 1
Least sandpiper, Pisobia minutilla (Vieillot)..... 1
Marbled godwit, Limosa fedoa (Linnaeus)...... 1
Willet, Catoptrophorus semipalmatus (Gmelin) 1
Upland plover, Bartramia longicauda (Bechstein) 1
Buff-breasted sandpiper, Tryngites subruficollis (Vieillot) 1
Spotted sandpiper, Actitis macularius (Linnaeus) 2
Long-billed curlew, Numenius americanus Bechstein 1
Golden plover, Charadrius dominicus Müller.... 4
Turnstone, Arenaria interpres (Linnaeus)..... 1
Rough-legged hawk, Archibuteo lagopus sancti-johannis (Gmelin).................... 1
Great horned owl, Bubo virginianus (Gmelin)... 1
Pileated woodpecker, Phloeotomus pileatus (Linnaeus) 2
Redpoll linnet, Acanthis linaria (Linnaeus)........ 2
White-crowned sparrow, Zonotrichia leucophrys (Forster) 1

Sanderson, W. Rensselaer

American scoter, Oidemia americana (Swainson and Richardson) 2

Birds' nests and eggs

Hart, C. G. East Berlin, Conn.

Red-shouldered hawk, Buteo lineatus (Gmelin), nest and three eggs.

Cooper hawk, Accipiter cooperi (Bonaparte), nest and four eggs.

Reptiles

Ward's Natural Science Establishment, Rochester

Harp turtle, Dermochelys coriacea (Vandelli) cast 1

Amphibia

Ward's Natural Science Establishment, Rochester

Common tree toad, Hyla versicolor Le Conte, casts. 3

ARCHEOLOGY

Donation

Auringer Collection, donated by Dr Albert Vander Veer

Quartz spear	1
Arrow points, stone	180
Stone hoes	6
Spears	28
Hammers	30
Cache of flints	40
Pestles, roller	6
Metates	4
Slate knives, Esquimeaux	4
Steel lance head	1
Beads, 1 string	1
Pitted stones	20
New sinkers	102
Worked stones	184
Notched axes	12
Celts	54
Pottery fragments	52
Pot stone, worked fragments	21

Bird, Daniel. Troy

Skull and fragments of skeleton	1

Burmaster, E. R. Irving

Mound skull	1
Pottery fragments	4
Stone celt	1
Crude celt	1
Hammer stones	1

Holden, Hon. J. A. Glens Falls

Cylindrical pestle	1

Hurd, A. S. Troy

Specimen fine semilunar knife	1
Specimen scraper	1
Fragments pottery	10

Purchase

Tann, Mrs Charles. Troy

Triangular flints	16
Arrow points	71
Spears	16
Leaden effigy of tomahawk	1

Kopple, Pauline. New York
Carved wooden crucifix.............................. 1
Schmits
Baskets.. 3
Nicholson, A. S. Neopit, Wis.
Bark house... 1
Bradly, E. R. Cazenovia
Grooved shaft stone.................................. 1

Collection in the field

Parker, A. C.
Algonquin bark hamper................................ 1
Brass medal.. 1
Wooden spoons.. 2
Seneca mask.. 1
Stone hatchet.. 1

THE MOUNT MORRIS METEORITE

BY H. P. WHITLOCK

The State Museum has recently acquired by purchase a meteoric fragment which represents a hitherto unrecorded fall, and adds another occurrence to the small number of authenticated meteorites from New York State.

The specimen was found in December 1897 by Mr Frederick H. Crofoot, on the Landers farm about one and one-half miles south of Mount Morris, Livingston county, N. Y. It measures 30 mm x 20 mm x 13 mm and weighs 12.48 grams. The shape roughly suggests a rhomboidal solid similar to a distorted rhombic-dodecahedron, although this rough shape has in all probability no significance and is purely accidental. One side has been roughly polished, showing the structure.

The structure classification which was determined as nearly as possible macroscopically, places this meteorite in the group Chondrites, the ground mass being composed of spherulitic chondrules of enstatite and olivine of irregular sizes. The ground mass is broken by irregular shotlike grains of iron.

Notwithstanding the small size of the specimen, all the evidence appears to confirm the statement of Mr Crofoot that the present fragment represents the entire bulk of this fall.

Figure 1 gives a full-size view of the meteorite, showing the general shape and character of the surface. Figure 2 shows the polished surface of one side; the brilliantly reflecting portions of the surface are the iron particles included in the ground mass.

Fig. 1 Full-size view showing general shape and character of the surface

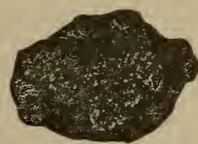


Fig. 2 Full-size view showing polished surface of one side

The following list gives the authenticated meteorites which have been found in New York State.

LOCALITY OF FALL	REPRESENTED IN N. Y. STATE MUS. COLL.	DATE OF DISCOVERY	PUBLISHED ACCOUNT	AUTHOR
Bethlehem, Albany co....	×	[a]Aug. 11, 1859	Am. Jour. Sci. (2). 28:300.	C. V. Shepard
Burlington, Otsego co.....	×	Previous to 1819	Am. Jour. Sci. (1). 46:401	James Pierce
Long Creek, Jefferson co..	....	....	In British Museum Coll...	....
Lockport, Niagara co.....	....	1818	Am. Jour. Sci. (1). 48:388.	B. Silliman
Mount Morris, Livingston co....................	×	1897	....	....
Scriba, Oswego co........	×	....	Am. Jour. Sci. (1). 40:336.	C. V. Shepard
Seneca Falls, Seneca co....	....	....	Am. Jour. Sci. (2). 2:39..	C. V. Shepard
Seneca River, Cayuga co..	....	....	Am. Jour. Sci. (2). 14:439.	E. W. Root
Tomhannock, Rensselaer co....................	×	....	Am. Jour. Sci. (3). 34:60..	Bailey
Yorktown, Westchester co.	....	....	....	....

[a] Observed fall.

EARLY PALEOZOIC PHYSIOGRAPHY OF THE SOUTHERN ADIRONDACKS

BY WILLIAM J. MILLER

INTRODUCTION

For many years the problem of the early Paleozoic physiography of the Adirondack region has been an important one to all interested in the geological history of northern New York. Observations made during the past ten or fifteen years have thrown much light upon this problem, especially significant being the work of Cushing, Kemp, Ruedemann, and Ulrich. For some years the writer also has been studying the geology of the southern Adirondacks, the five quadrangles which he has mapped in detail all having important bearings upon the subject. It is the purpose of this paper to bring together old and new observations in an attempt to reconstruct the major physiographic features of the southern Adirondack region during the Cambric and Ordovicic periods. The Black river, Mohawk and Champlain valleys will be discussed only in so far as facts from those regions have a direct bearing upon the problem. Since the Paleozoic rock outliers in the southeastern Adirondacks are particularly significant in this connection, they will be duly emphasized.

Some of the principal questions discussed are the following:

1 What was the character of the surface of the Precambric rock upon which the early Paleozoic sea encroached?

2 Were the early Paleozoic sediments deposited in embayments of the sea extending into the Precambric rock area or did they form a more general mantle over the Precambric rocks?

3 Was the southern Adirondack region ever completely submerged during the Paleozoic era and, if so, when?

4 Where were the principal land areas located during the Cambric and Ordovicic periods?

5 Does the present northeast-southwest main axis of elevation through the Adirondacks also have an early Paleozoic significance?

CAMBRIC PHYSIOGRAPHY

The Cambric peneplain. As is well known, the whole Adirondack region was above water and undergoing erosion during the early and middle Cambric. This is proved by the total absence of the early and middle Cambric strata and also because there is not the slightest evidence that any such strata ever were deposited over the region. Furthermore there is every reason to believe that this important erosion interval was inaugurated long before the opening of the Paleozoic era. As a result of this vast erosion the whole Adirondack region had, by the opening of Potsdam (late Cambric) time, become worn down to the condition of a more or less well-developed peneplain.

As will be shown below, the distribution of the strata proves that the northeastern and eastern borders of the Adirondacks sank below sea level first in early Potsdam time; then the southeastern and southern portions in late Potsdam, Theresa and Little Falls times; and last the southwestern border well along in Ordovicic (Pamelia) time.

The peneplain surface of the Precambric rock under the Paleozoic strata has been carefully studied on all sides of the Adirondacks and it has been fully demonstrated that it is roughest along the northeastern and eastern sides; less rough along the southeastern and southern sides; and very smooth along the southwestern side. Even where roughest the differences of elevation never amount to more than a few hundred feet, while on the southern side Cushing[2] and the writer[10] have each found knobs or ridges of hard Precambric rock projecting upward from fifty to eighty feet into the Cambric strata, though these appear to be extreme cases of ruggedness of the surface of the peneplain. Along the southwestern border of the Adirondacks the writer has shown by his mapping of the Port Leyden quadrangle[9] that the surface of the peneplain is there remarkably smooth. This increasing smoothness of the peneplain from northeast to southwest is precisely what would be expected because the southwestern side of the Adirondacks remained dry land much the longest time. In the eastern Adirondacks Kemp[6]

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[2] Page 57–58. The footnote numbers refer to the numbered references given in the list at the end of this paper.

[10] Page 51.

[9] Pages 40–41.

[6] Pages 408–12.

has argued that the major relief features immediately prior to the advent of the Potsdam sea were valleys carved out along the belts of weaker Grenville strata, especially the limestones.

Positive evidence regarding the physiographic condition of the interior Adirondack region during Cambric time is of course lacking, but there is no reason whatever for thinking that it was essentially different from the immediately surrounding regions except probably that the general altitude was somewhat greater.

Encroachment of the late Cambric sea. Cushing[3] has proved that the Potsdam sea encroachd upon the Adirondack region from the northeast toward the southwest because the sandstone formation of that age progressively thins from a thickness of over one thousand feet to disappearance in the southwest. During the encroachment of this late Cambric sea, did the waters enter distinct embayments or estuaries as Kemp[6] has suggested or did they form a more regular shore line? Along the eastern side, where the topography was moderately rugged, such embayments were quite likely physiographic features of some importance due to a drowning of the valleys which had been cut out along the belts of weaker Grenville strata. In the southern Adirondacks, however, the evidence is decidedly against the encroachment of the late Cambric sea by setting up anything like well-defined embayments or estuaries extending into the area of Precambric rock.

The outliers of Palezoic rock in the southeastern Adirondacks are of first importance in this connection. All the definitely known outliers well within the Precambric rock area of this region are given in the following list:

1 A small exposure of Potsdam sandstone near the southwestern corner of the Elizabethtown quadrangle and near the village of North Hudson.

2, 3, 4 Three outliers of Potsdam sandstone along the eastern side of the Paradox Lake quadrangle.

5 The Little Falls dolomite outlier (probably with underlying Potsdam) at Schroon Lake village, Schroon Lake quadrangle.

6 A small outlier of Potsdam sandstone one and one-half miles west of the village of North River in the northeastern corner of the Thirteenth Lake quadrangle.

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[3] Pages 279–80.
[6] Pages 408–12.

7 A small outcrop of Theresa sandstone and dolomite (probably with underlying Potsdam) near the northern border of the Luzerne quadrangle and one mile due west of High Street village.

8 The outlier in the Sacandaga valley at Wells, Lake Pleasant quadrangle. This, the largest and most interesting of all the outliers, shows Potsdam sandstone, Theresa transition beds, Little Falls dolomite, Black River (Lowville) limestone, Trenton limestone, and Canajoharie (Trenton) shale.

9 An outlier showing Theresa beds, Little Falls dolomite, and Black River limestone in the Sacandaga river valley of the Lake Pleasant quadrangle and between one and three miles northwest of Hope postoffice.

Of these, numbers 7 and 9 have been discovered by the writer within the past three years.

Besides the above there are a number of other outliers close to the main body of Paleozoic strata as: In the valley one and one-half miles west of Northville (Broadalbin quadrangle) and including Potsdam, Theresa and Little Falls strata; several Potsdam sandstone outliers within the tongue of Precambric rock lying just east of Lake George; and several others in the northwestern portion of the Ticonderoga quadrangle.

Wherever detailed geologic maps have been recently made in the southeastern Adirondacks the region is shown to be literally cut to pieces by numerous normal faults, as many as fifteen to thirty being clearly recognizable within single quadrangles. Most of the prominent faults strike northeast-southwest with throws usually ranging from a few hundred to two thousand or more feet. It is important to note that all the outliers above mentioned as occurring well within the Precambric rock area, except possibly those of the Paradox Lake quadrangle, lie on the downthrow sides of such faults. In the case of the Wells outlier (No. 8) the valley is of the nature of a " graben " or fault-trough with a prominent fault on each side so that the block of Paleozoic rock has been dropped down no less than sixteen hundred feet to its present position. Thus there appears to be no escape from the conclusion that the valleys containing these outliers have been largely produced by faulting and that the Paleozoic strata formerly lay at a much higher level, that is, the general level of the Precambric rock surface.

It should be pointed out that the possible exceptions in the cases of the outliers along the eastern side of the Paradox Lake quadrangle, as well as those of the Ticonderoga quadrangle and to the east of Lake George, all lie close to the general Paleozoic rock area and in that portion of the southern Adirondacks upon which the late Cambric sea first encroached and where the topography was most rugged so that it is quite possible that local embayments receiving Cambric sediments did there exist.

In the cases of all the other and important outliers there does not appear to be any direct evidence favoring the existence of embayments nor any need for such an explanation to account for the phenomena of the outliers. Simple downfaulting of the Paleozoic strata has often carried masses of these so far down that remnants have been protected from complete removal by subsequent erosion. As already shown the southern Adirondack region was, by the beginning of the Potsdam, worn down to a peneplain upon whose surface only a few very minor irregularities existed. This being the case, anything like prominent embayments or estuaries could not possibly have existed. Another argument decidedly against the embayment idea comes out of the character of the sediments within the outliers. Thus the dolomite in the Schroon Lake and Wells outliers is a distinctly marine formation of exactly the same character as that of the general Paleozoic rock area. Or again, the Canajoharie black shale at Wells is both faunally and lithologically distinctly marine and precisely like that of the Mohawk valley. Estuarine deposits would show certain distinct local variations and hence the very uniformity of sediments in the outliers precludes the possibility of deposition in estuaries. Thus we are forced to conclude that when the early Paleozoic sea encroached upon the southern Adirondacks, the shore line was fairly regular, with possibly some very small local embayments along the eastern side, and that a general mantle of sediments was deposited over the whole southeastern Adirondack region.

Extent of the Cambric seas. Nearly all the Paleozoic outliers show the presence of Potsdam sandstone, and in the few cases where it does not actually outcrop it is most likely present though concealed from view. In the southern Adirondacks no Potsdam sandstone outcrops west of a nearly straight northeast-southwest line passing through the outliers at or near North Hudson (No. 1), North River (No. 6), Wells (No. 8), and through the village of St Johnsville in the Mohawk valley. Thus we are certain that the shallow Potsdam sea overspread practically the whole southern Adirondack region east of this line except for a few local knobs or ridges of hard Precambric rock which remained above the sea level. A fine example of such a local projection above the Potsdam sea level has been described by the writer[10] in his report on the Broadalbin quadrangle. That the Potsdam shore line extended a short but unknown distance farther west than Wells and North River is certain because a considerable thickness of sandstone is still represented at those places. This conclusion regarding the position of the Potsdam shore line is in harmony with the statement of Ulrich and Cushing[16] when they say: "It is thought that along the Mohawk line the Potsdam shore had a southwesterly trend more to the south than the present Precambric margin, the two meeting at an angle; east of the meeting point the Potsdam appears under the Little Falls, while west of it the Potsdam is either absent or erosion has not yet cut down to it."

That the southwestern Adirondacks were not submerged under the Potsdam sea is proved by the complete absence of the sandstone from the southwestern border; the very character of the sediments (sands and pebbles) which demands nearness to a mass of Precambric rock; and the negative evidence from the fact that no outliers of Potsdam have ever been found in this region. The Potsdam sea did extend up the St Lawrence valley as shown by the presence of the sandstone there.

Thus we conclude that a long, low, land area of Precambric rock extended in a northeast-southwest direction through the Adirondack region, and that this height of land in Potsdam time had almost exactly the same position as the present main axis of elevation of the mountains.

Since the Potsdam sandstone grades into the succeeding, alternating sandstone and dolomite beds of the Theresa and the two formations have almost precisely the same distribution, we are safe in asserting that the physical geography conditions of Theresa time were essentially like those of Potsdam time except that the southeastern Adirondacks were then even a little more submerged.

The distribution of the Little Falls dolomite which succeeds the Theresa beds without unconformity along the southern and

[10] Pages 51–52.

[16] Page 139.

southeastern border of the Adirondacks and in the outliers at Schroon Lake and Wells shows that the Little Falls sea extended over at least as much of the southern Adirondacks as did the Potsdam-Theresa seas. In the Mohawk valley region it extended considerably farther westward overlapping upon the Precambric rock to the southwest corner of the Wilmurt quadrangle where the dolomite thins out to disappearance. From this point northwestward the Precambric rock margin shows no dolomite, thus proving the absence of the Little Falls sea there. The very rapid decrease in thickness of the dolomite from four hundred feet at Little Falls to complete disappearance just beyond the northern boundary of the Little Falls quadrangle also shows the limit of the sea in that district. Accordingly there must have been a large land mass in the southwestern Adirondack region. The very presence of so many sand grains in the dolomite (giving rise to the old name Calciferous sandrock) requires that it was deposited comparatively near a land mass. Thus during late Little Falls time the eastern portion of the southern Adirondacks was submerged while the western portion remained dry land, the shore line extending from the southwest corner of the Wilmurt quadrangle most probably in a northeasterly direction through the southern Adirondacks. That its shore line was, in general, a little farther westward than that of the Potsdam sea is strongly suggested by the fact that all the Cambric sediments were gradually accumulated in a downsinking trough occupying the southeastern Adirondack area. This idea of a gradual westerly encroachment of the Cambric sea is borne out by the following facts: The thickness of the Cambric section within the Saratoga quadrangle is from four hundred to five hundred feet; within the Broadalbin quadrangle near Northville four hundred to four hundred and fifty feet; and at Wells about two hundred feet. This rapid decrease in thickness of two hundred feet from Northville to Wells within a distance of fourteen miles shows a westward to northwestward encroachment of the Cambric sea and that the downward slope of the surface here receiving Cambric sediments was fourteen feet a mile toward the southeast.

According to Ulrich and Cushing[16] there is a distinct stratigraphic break represented by a notable erosion unconformity at the top of the Little Falls dolomite. Thus all available evidence supports the idea that, by the close of the Cambric period, subsidence

[16] Page 129.

ceased and the whole southern Adirondack region was raised above sea level and underwent erosion. The western portion of this land area was of Precambric rock while the surface rock in the eastern portion was Little Falls dolomite.

To summarize for the Cambric period: All evidence is decidedly against a complete submergence of the southern Adirondack region during the late Cambric period, the land mass of the time having occupied at least all of Hamilton county except its southeastern portion; all the northern half of Herkimer county; and most of the eastern portion of Lewis county. This axis of elevation most likely continued northeastwardly through the Adirondack region to its northeastern portion and occupied about the same area as the present main axis of elevation of the mountains. The close of the Cambric witnessed an uplift sufficient to convert the whole southern Adirondack region into dry land.

ORDOVICIC PHYSIOGRAPHY

Early Ordovicic. According to Ulrich and Cushing[16] the Tribes Hill limestone is the earliest Ordovicic formation. Its distribution demonstrates that the Mohawk valley to a little northwest of Little Falls and the lower Black river valley were submerged. Its total absence from the southwestern Precambric boundary, from the outlier at Wells, and from the vicinity of Northville and Saratoga Springs strongly suggests that little if any of the southern Adirondack region was submerged under the Tribes Hill sea. This limestone is probably not present in the Champlain valley but, if it is, a little of the eastern border of the Adirondacks may have been submerged. It would seem, therefore, that this Tribes Hill submergence was not as extensive as that of Little Falls time. After the deposition of the Tribes Hill limestone, however, there was a long erosion interval continuing to Black River time and hence because of removal of Tribes Hill limestone by this erosion it is more than likely that the present outcrops do not indicate the full extent of the Tribes Hill sea. At any rate there is not the slightest direct evidence for any considerable submergence of the southern Adirondack area at this time.

During the long interval between Tribes Hill and Black River times the whole southern Adirondack region was above sea level except locally along the western border for a short time when

[16] Pages 128–30.

the Pamelia (Chazy) limestone was being deposited in the Black river valley and also locally along the eastern border when certain other limestones of the Chazy group were being laid down in the Champlain trough.

For most part the various Black River limestone members are thin and patchy in their distribution except in the Black river valley, and no attempt is here made to enter into the details of physiography and oscillations of level in Black River time. Suffice it to say that early Black River (Lowville) limestone is present on all sides of the southern Adirondacks and in the outlier at Wells, it being but a few feet thick in the eastern and southern portions and fifty to sixty feet thick along the western border. Therefore, judging by the areal distribution and thinness of the Lowville we are practically certain that the central western portion of the Adirondack area was not submerged during early Black River time. Thin limestone deposits of late Black River age are confined to the vicinity of Watertown (Watertown limestone) and along the eastern and southeastern borders of the Adirondacks (Amsterdam limestone) with deposition in these two regions not occurring simultaneously. Thus there could not have been anything like extensive submergence of the southern Adirondacks in late Black River time.

The widespread unconformity at the summit of the Black River group of limestones shows that a general upward oscillation occurred and that the whole southern Adirondack region became dry land before the succeeding Trenton submergence.

Late Ordovicic. During Trenton time there was a widespread submergence of much of the southern Adirondack region as shown by the existence of Trenton limestone or shale hundreds of feet thick on all sides of the region and even in the outlier at Wells. The limestone is almost wholly confined to the western side, there being but a few feet of limestone at the base of the Trenton on the eastern side where thick shales (Canajoharie and Schenectady) comprise nearly the whole section.

Considering the thickness (about four hundred feet) of the Trenton limestone in the upper Black River valley and the slope of the surface[9] on which deposition occurred, the Trenton sea could not have extended more than forty miles eastward into the Adirondack area. If we consider deposition to have taken place in a distinctly downwarped trough, then the Trenton sea must have extended in

[9] Page 43.

considerably less than forty miles, and this is the most likely view. By a similar line of reasoning Cushing[2] has shown that the Trenton sea could not have reached more than ten miles north of the north boundary of the Little Falls quadrangle. The thickness of about three hundred feet of Trenton (mostly shale) in the outlier at Wells shows that the Trenton sea must have reached at least a few miles north and west of that locality. Pebbles of Precambric rock and grains of sand in the Trenton limestone at Wells, however, make the existence of near-by land (Precambric rock) practically a certainty as argued by Kemp.[7]

From the above statements we conclude that dry land existed in the region of southwestern Hamilton county and also most probably over all of northern Hamilton county. It is worthy of note that this Trenton land mass, with northeast-southwest trend, occupied the same region as the present belt of highest land in the southern Adirondacks, and also that this land mass, though now smaller, occupied the same position as that of late Cambric and early Ordovicic times. The absence of Paleozoic rock outliers west of a northeast-southwest line through Wells and North River at least affords interesting negative evidence in harmony with this view.

Regarding Utica and Postutica times the results of recent work are decidedly against submergence of the whole Adirondack region. Considering the great thickness of Paleozoic strata; the slope of the surface of the Precambric rock; and the existing altitudes within the Adirondacks, Walcott, Cushing and the writer have all been led to conclude that the late Ordovicic sea must have extended almost, if not quite, across the whole Adirondack area. Many years ago Walcott[17] said: "There was a practically conformable deposit of sediments against and over the area of the Adirondack mountains from early Cambric times to the close of the deposition of the Utica shales, except in the case of the unconformity by non-deposition between the Potsdam and the Chazy."

Later Cushing,[1] as a result of his studies along the northeastern border of the Adirondacks, said: "The basal Potsdam is found running up to an elevation of seventeen hundred fifty feet in the northern Adirondacks. With the relief of the region as it is now the deposition of the minimum thickness (four thousand feet) of

[1] Page 77.
[2] Page 61.
[7] Page 152.
[17] Pages 24–25.

the Paleozoic rocks assigned above on this Potsdam would leave none of the present peaks projecting above the general level." Again he stated:[3] "This submergence (Utica) apparently completely overswept the old Adirondack island, and that for the first time in its paleozoic history, with the possible exception of the latter part of the Trenton."

Still later the writer,[9] speaking of the Paleozoic sediments along the southwestern border of the Adirondacks, said: "This thickness (fourteen hundred feet) is great enough so that even after allowing for decreased thickness due to overlap and a possibly increased slope (receiving sediments) as the heart of the Adirondacks was approached, we seem to have here a strong argument in favor of the submergence of the region for many miles to the east and northeast of Port Leyden, so that by the close of the Lower Siluric (Ordovicic) the submergence extended to, or close to, the heart of the Adirondacks."

This line of reasoning, however, does not regard the possible importance of downwarping troughs of deposition. As already shown in this paper, such troughs of deposition clearly did exist from Potsdam through Trenton time and we have no good reason to doubt their existence during Utica and late Ordovicic time as well. In a recent paper Cushing[4] says: "As the evidence accumulates it points more and more strongly to deposit in downwarping troughs, in which large depth of deposit by no means implies extensive overlap on the shores. . . . Even when submerged at the same time, as in the Trenton, the deposits on the two sides (east and west) are so different both lithologically and faunally, as to indicate that the two basins had no very direct connection."

Some years ago Ruedemann,[14] by noting the parallel positions of the graptolites in the black shales at Wells, Dolgeville (Herkimer county), along Nine Mile creek near Trenton Falls (Oneida county), etc., proved the existence of a late Ordovicic ocean current across the southern side of the Adirondack region. The proof for the existence of such an ocean current by no means implies that it swept entirely across the whole Adirondack region, and hence we have here no argument for a complete submergence of the region at that time. In fact Ruedemann gives good reason for the belief

[3] Page 285.
[4] Page 144.
[9] Page 43.
[14] Pages 367–91 and [15] Pages 75–81.

that this current which was a southerly to southwesterly one along the eastern side of the Adirondack region changed to a more westerly current along the southern side, and this is precisely what would be expected in the case of a current sweeping partly around a land mass occupying the central Adirondack area.

Further, the very recent work of Ruedemann shows that the shales of the lower Mohawk valley and Champlain valley which have always been regarded as of Utica age are, in reality, of Trenton (Canajoharie and Schenectady) age; that the Utica shale is wholly absent from those regions; and that there is no evidence of their ever having been deposited there. Hence any argument for the complete submergence of the Adirondacks during Utica time receives a serious setback.

In the Black River valley the Utica is followed without interruption by the Frankfort and Pulaski shales and sandstones. The combined thickness (about nine hundred feet) there of the Utica, Frankfort, and Pulaski clearly implies, even considering deposition in a downwarping trough, that the sea spread well over the western side of the southern Adirondack region. However, the very character of the Frankfort and Pulaski rocks, which contain so much sandstone, implies comparative nearness to land undergoing pretty rapid wear and more than likely this land mass, in part at least, lay in the same general region as that of earlier time. In the vicinity of Utica the Pulaski beds are missing, signifying dry land there during that time, while on the southern and eastern sides the only strata of Posttrenton age are the Indian Ladder beds of Albany county which are thought to correlate with the Frankfort beds and which signify local subsidence at that time for that region. The outlier at Wells furnishes no data for Posttrenton time because of the absence of any strata younger than Canajoharie age.

South of Utica there is an important stratigraphic break between the Oneida (Siluric) conglomerate and the underlying Frankfort (Ordovicic) shales. This unconformity is very distinct so that prior to the deposition of the Oneida the region around Utica was well above sea level and undergoing erosion. The only possible source of the pebbles in the Oneida formation would seem to have been an area of Precambric rock, more than likely situated in that same portion of the Adirondacks which never became submerged during the Cambro-Ordovicic periods. That this uplift, which began in the late Ordovicic, affected the region as far eastward as the Hudson valley, and that the land remained above sea level for a long time is shown by the complete absence of the Oneida conglomerate and the nearly complete absence of the Clinton and Niagara formations from southern Herkimer county eastward. Such a widespread and important elevation of the land in the Mohawk valley region almost certainly upraised the whole southern Adirondacks except possibly the very western border. Cushing[3] has given evidence to show that the northeastern Adirondack area was distinctly elevated even earlier in the late Ordovicic than the southern area. It is more than probable that this period of elevation in northern New York culminated with the great Taconic revolution.

To summarize for Ordovicic Posttrenton time we find that a considerable portion of the western side of the Adirondacks was submerged, while the whole middle and eastern portion was dry land except possibly locally along the southeastern border during the deposition of the Indian Ladder beds. After the deposition of the Frankfort shales there was an important uplift (inaugurating the Taconic revolution) which brought the whole southern Adirondack area, except probably the very western border, well above sea level, and we have no good reason to think that any considerable portion of the Adirondack region was ever again submerged.

Some of the more important conclusions, regarding the early Paleozoic physiography of the southern Adirondacks, reached in this paper are the following:

1 The early Paleozoic sea encroached upon a more or less well-developed peneplain in the Adirondack region, this peneplain being moderately rugged in the northeastern and eastern portions; less so in the southern portion; and very smooth in the southwestern portion, such a difference in character of the peneplain no doubt being due to the fact that the southwestern portion longest remained above sea level.

2 When the early Paleozoic sea encroached upon the region it did not set up embayments or estuaries in the Precambric rock area, except possibly to some extent on the eastern side, as shown by the peneplain character of the Precambric rock surface; the typical marine character of the deposits in the Paleozoic rock outliers; and the downfaulted structure of the outliers.

3 The region was never completely submerged during the Paleozoic era though, at the time of maximum submergence during the Trenton, only a comparatively small land mass remained.

[3] Page 285.

4 The land areas varied considerably in extent from time to time, but the principal area of unsubmerged Precambric rock ran in a northeast-southwest direction through the southern Adirondack region and most likely continued through the northern region.

5 This prominent northeast-southwest structural belt or axis of elevation, occupying practically the same position as the present main axis of elevation of the mountains, has played an important part in the geological history of northern New York.

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THE GARNET DEPOSITS OF WARREN COUNTY, NEW YORK

BY WILLIAM J. MILLER

INTRODUCTION

The principal garnet mines of the United States are located in Warren and Essex counties of the eastern Adirondacks, those of Warren county — especially the Hooper and Rogers mines below described — being the greatest producers. All the Warren county mines are in its northwestern portion and within six or eight miles of North Creek village which is at the terminus of the Adirondack branch of the Delaware and Hudson Railroad.

GENERAL GEOLOGIC FEATURES

The garnet mines of Warren county lie wholly within the precambrian rock area of the Adirondacks. The oldest rocks in the garnet region are the highly metamorphosed sediments of the Grenville series. Detailed mapping by the writer has shown extensive areas of Grenville which are unusually rich in limestone and closely associated hornblende gneiss.

Next in age come plutonic igneous rocks such as syenite, granite, and granite porphyry which are clearly intrusions into the Grenville and all of which are differentiation products from the same great cooling magma. Of these rocks the syenite is, perhaps, the most abundant. It is a medium to fairly coarse grained, generally quartzose and hornblendic rock with sometimes a more basic variety carrying a green pyroxene. The granite is highly quartzose and always contains hornblende or biotite or both. The granite porphyry is biotitic to sometimes hornblendic with large, pink, feldspar crystals imbedded in a fine to medium grained matrix. All these rocks are distinctly gneissoid.

As a result of the great intrusion, the Grenville in some cases appears to have been pushed upward and to have been largely removed by erosion since; in other cases the Grenville was more or less engulfed by, or involved with, the molten flood as shown by the numerous inclusions and the areas of mixed gneisses; while in still other cases the Grenville rocks were left practically intact as shown by the large areas of pure Grenville.

Minor intrusives, cutting all the above masses, occur as bosses or dikes of gabbro, pegmatite, or diabase.

An important structural feature is the presence of numerous normal faults which have greatly dissected the region.

DESCRIPTION OF THE GARNET DEPOSITS

There are at least seven localities in Warren county where garnet mining has been carried on as follows: (1) Rogers (Barton) mine[1] near the top of Gore mountain and three and one-half miles west-southwest of North Creek; (2) near the top of Oven mountain and four miles south of North Creek; (3) the Rexford mine, one and one-third miles a little east of south of North Creek; (4) the Parker mine just southwest of Daggett pond and four and one-half miles northwest of Warrensburg; (5) the Sanders Brothers mine near the mouth of Mill Creek and two miles east of Wevertown; (6) two and three-fourths miles north of North Creek; and (7) the Hooper mine just east of the northern portion of Thirteenth lake. Of these, only the Rogers, Sanders Brothers, and Hooper mines are now in operation. The Rogers and Hooper mines lie within the Thirteenth Lake quadrangle and the others within the North Creek quadrangle. All the above mines have been visited by the writer.

1 In the Rogers mine the mode of occurrence and the size of the garnets are of unusual interest. The matrix or rock carrying the garnets is a gray, medium grained gneiss which, in thin section, shows: 20 per cent orthoclase; 20 per cent labradorite; 40 per cent hornblende; 15 per cent hypersthene; 3 per cent biotite; together with a little magnetite and zoisite. Imbedded in this gray matrix are numerous, well-scattered, translucent, reddish-brown garnets, those with diameters up to five or six inches being very common, while the largest ones taken out are said to have been about the size of a bushel basket. These garnets, which are of the almandite variety, are always pretty badly crushed or coarsely granulated and they never show crystal outlines.

A remarkable feature is the never failing occurrence of a rim or envelop of pure, black, medium grained hornblende crystals which completely inclose each garnet. Occasionally a half inch

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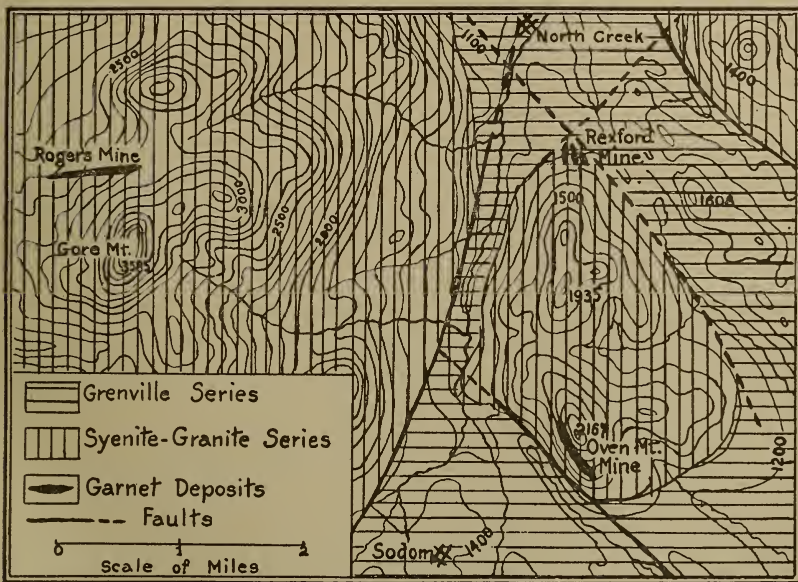
[1] This is called Moore's mine on the topographic map.

irregular mass of acid plagioclase or a crystal of biotite may lie between the garnet and the hornblende rim. As a rule the hornblende rims increase in width with the size of the garnets, some rims being as much as two or three inches wide. These reddish-brown garnets, completely surrounded by the black hornblende rims which are, in turn, imbedded in the gray gneiss matrix, present a striking appearance in the walls of the great mine pits.



Geologic and topographic sketch map of portions of the North Creek and Thirteenth Lake (U. S. G. S.) sheets, showing the mode of occurrence of those garnet deposits which are lenslike inclusions in the syenite or granite.

This garnet-bearing rock clearly occurs as a long, narrow, lenslike inclusion of Grenville gneiss in the great mass of Gore mountain syenite. The inclusion is fully three-fourths of a mile long, with nearly east-west strike. Several large openings have been made in it and, in the very large more easterly pit, the width of the inclusion is more than one hundred feet. The garnet rock is removed by blasting and reduced by sledge hammers after which the garnets are picked out by hand.

2 In the Oven mountain mine the mode of occurrence is precisely like that in the Rogers mine. In thin section the matrix

shows: 20 per cent orthoclase; 25 per cent oligoclase to labradorite; 50 per cent hornblende; 2 per cent biotite; 2 per cent magnetite; together with a little pyrite, zoisite, and apatite. As compared with the similar rock from the Rogers mine the lack of hypersthene is noteworthy. Imbedded in the gray matrix are numerous shattered, reddish-brown garnets (almandite) which range in size up to several inches in diameter. Black hornblende rims are invariably present around the garnets.

This garnet rock is a long, narrow, well-defined inclusion of Grenville gneiss in a granitic facies of the great syenite-granite intrusive body.

This mine has not been worked for about twenty years. After blasting out the garnet-bearing rock and reducing it by sledge hammers, the garnets were picked out by hand.

3 At the Rexford mine the type of occurrence is much like that of Oven mountain, only here there appear to be several smaller inclusions of the garnet-bearing gneiss instead of one, and the country rock is a very gneissoid quartz-syenite. Garnets up to five inches across, always with hornblende rims, were noted. There are several mine openings but none have been worked for about fifteen years.

4 The old mine on the Parker farm occurs in a mixed gneiss area with granitic syenite and Grenville interbedded parallel to the foliation strike. These bands of rock are often twenty to forty feet wide, one of them being made up of a nearly pure, granular, medium grained mass of irregular crystals of reddish-brown garnet and bright green pyroxene (coccolite?). About twenty years ago this band of garnet rock was mined, crushed and put into barrels, there being no attempt to separate the pyroxene from the garnet.

5 At the Sanders Brothers mine the mode of occurence is very similar to that of the Parker mine, the bands of Grenville being, however, somewhat less pronounced and numerous. The rock which is mined is pretty badly granulated and consists mostly of intimately associated reddish-brown garnet and green pyroxene (coccolite?) in small grains, with sometimes a little quartz and feldspar. There are some streaks or patches of nearly pure garnet. Work began in 1907 on the south side of the creek, but now all the mining is confined to the north side. The garnet-pyroxene rock is crushed, put into bags, and shipped to all parts of the world.

6 Years ago an attempt was made to mine the garnets which occur in the coarse, feldspar, biotite, garnet, Grenville gneiss two and three-fourths miles north of North Creek, but this locality is of no special interest.

7 At the Hooper mine the garnets occur as crystals (dodecahedral) often with good crystal boundaries, up to an inch or a little more in diameter. They are thickly scattered through a medium to moderately coarse grained, dark to light gray, very gneissoid, hornblendic rock which has the composition of a basic syenite or an acidic diorite. It is important to note that these garnets never show the rims of hornblende. In fact the garnets may sometimes be almost surrounded by feldspar. This type of occurrence has not been observed on a large scale at any of the other localities within the county, though a rock almost exactly like it occurs at the Rogers mine as a distinct zone (wall rock) intermediate between the typical garnet-bearing gneiss and the country rock of syenite, where the garnet rock grades perfectly into the syenite. The significance of this fact will be explained below.

The deposit is an extensive one and a very large mine pit has been opened up. After blasting out the rock, it is somewhat reduced by sledge hammers, then taken on cars to the mill where it is crushed. By the use of an ingenious method, involving the use of jigs, the garnet (almandite) is almost perfectly separated from the rest of the crushed rock which is of lower specific gravity than the garnet.

ORIGIN OF THE GARNETS

All modes of occurrence of garnets observed by the writer on the North Creek and Thirteenth Lake sheets are summarized as follows:

1 As crystals or grains in various Grenville rocks, for example, the garnet-pyroxene gneiss; the hornblende-garnet gneiss; biotite-garnet gneisses, etc.

2 As distinct crystals frequently occurring in all types of intrusive rocks — syenite, granite, granite porphyry, and gabbro — except the diabase.

3 As large more or less rounded masses with distinct hornblende rims in the long, lenslike inclusions of Grenville hornblende gneiss in syenite or granite.

4 As more or less distinct crystals (dodecahedral), without hornblende rims, in a certain special basic syenitelike or acidic dioritelike rock.

In case number 1 (for example, Parker and Sanders Brothers mines) the garnets have, in the usual manner, crystallized out of masses of sediments under conditions of thermal and dynamic metamorphism. These garnets are rarely as much as an inch across and their origin presents no problem of special interest.

In case number 2 the garnets appear mostly to have crystallized out of the original magmas, their formation possibly having been due to some assimilation of granville sediment by the syenite or granite. The facts that these garnets occur so sporadically and that actual examples of local assimilation have been observed in the region strongly favor this view. Since these garnets seldom attain a diameter of an inch and are so scattered, no attempt has ever been made to mine them. Sometimes, as in the gabbros, the garnets have often been produced secondarily, or after the cooling of the magma, because they commonly form reaction rims around other minerals.

Case number 3 (for example, Rogers, Oven mountain, and Rexford mines) is of particular interest because of the very large garnets surrounded by the reaction rims of hornblende.

Kemp and Newland[1] have briefly described a garnet deposit (formerly worked by the Messrs Hooper) just across the line in Essex county less than a mile west of the village of North River and four and one-half miles north of the Rogers mine. As judged by their description the type of occurrence appears to be similar to that in the Rogers, Oven mountain, and Rexford mines, though no mention of the hornblende rims is made. In conclusion they say:

The origin of this peculiar bed presents an interesting theme. The country rock is probably igneous. Its mineralogy and structure favor this derivation. The garnet rock must be either an altered form of a very impure limestone, or else a very basic igneous rock that was an original sheet or dike. The former supposition appeals more strongly to us.

Later Newland[2] says of the garnet deposits in general that:

The garnet is usually associated with a basic hornblende rock or amphibolite which forms bands and lenses in the more acid gneiss that constitutes the country rock.

In his brief description of the more recently worked garnet deposit of northern Essex county he speaks of the "amphibolite bands, which have been caught up during the intrusion of the

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[1] 17th An. Rep. N. Y. State Geol., 1897, pages 548–49.
[2] N. Y. State Mus. Bul. 102, page 71.

anorthosite, or have been folded into the latter and metamorphosed."

From these statements we see that three possible modes of origin of these garnet-bearing beds have been suggested, namely that they are: lenses of sedimentary rock actually included in the igneous rock; or sediments folded into the igneous rock and metamorphosed; or sheets or dikes of very basic igneous rock. Now the work of the writer shows that, without question, these garnets occur in lenses of Grenville sediments which were caught up or included in the great igneous masses at the time of their intrusion, the tremendous heat and pressure being especially favorable for a very complete rearrangement and crystallization of the masses (inclusions) of sediment which were pretty low in silica. These inclusions are portions of a great thickness of hornblende-garnet gneiss, frequently interbedded with limestone, of the Grenville series. This gneiss is a basic rock generally carrying several per cent of magnetite; sometimes considerable hypersthene; and little or no quartz. It is quite likely that some of the closely involved limestone was mixed with the inclusions of sediment during the process of metamorphism. It will at once be seen that such an iron-rich, silica-poor sediment was very favorable for the development of large garnets under the conditions of great heat and pressure which were brought to bear upon the lenslike inclusions in the molten syenite or granite.

The hornblende rims or envelops are quite certainly great reaction rims around the garnets, but just at what stage of the metamorphism they were produced is not at all clear to the writer. The rounded character of the garnets shows pretty clearly that the rims of hornblende are of secondary origin and that they were formed sometime after the crystallization of the garnets and possibly at the time when the pressure producing the foliation of the rocks of the region was brought to bear.

In case number 4 (Hooper mine) a clew to the origin of the garnets is furnished by a study of the wall rock in the Rogers mine on Gore mountain. In this latter case the typical garnet-bearing rock (No. 1 of the accompanying table) of the mine passes by perfect gradation, through an eight or ten foot zone, into a basic syenite or acidic diorite (No. 2 of the table) which contains distinct dodecahedral garnet crystals up to over an inch across but always without hornblende rims. This rock, in turn, grades into a hornblende (quartzless) syenite (No. 3 of the table) which merges into the typical country rock of quartz, hornblende syenite, these two latter rocks being at times somewhat garnetiferous. The writer is fully convinced that this transition zone (wall rock) has been formed by assimilation or actual melting or fusing together of the syenite and the border of the great inclusion at the time of the intrusion.

TABLE SHOWING THE MINERALOGICAL COMPOSITION OF THE MATRIX OF THE GARNET-BEARING ROCK IN THE ROGERS AND HOOPER MINES [1]

		Orthoclase	Plagioclase	Hornblende	Biotite	Hypersthene	Magnetite	Zoisite	Apatite	Pyrite	Zircon
Rogers mine.......	1	20	Lab. 20	40	3	15	1	1			
	2	30	Ol.-an. 30	36			1	2	little	1	
	3	50	And. 25	24				1	little		
Hooper mine.......	4	42	Ol.-and. 20	30	5	2		½			½
	5	30	Ol.-and. 35	33	½	½	1				little
	6	40	Ol.-and. 20	35		4	1				

[1] A close approximation to percentage by volume only is intended.

As shown in the field, in hand specimens, and in thin-sections the garnet rock (Nos. 4, 5, and 6 of the table) at the Hooper mine is almost exactly like the wall or transition rock of the Rogers mine, and it also appears to grade into the country rock. In each case the garnets never show reaction rims of hornblende and the garnets often show good crystal outlines. In the Hooper mine this transition or intermediate rock makes up practically the whole mass which is mined and is thus much more extensive than at the Rogers mine. All evidence points to the origin of the Hooper mine rock as due to rather thorough melting of an admixture of syenite and Grenville sediment where the Grenville inclusion was perhaps deeper down in the magma and hence subjected to much greater heat, or possibly a number of smaller hornblende gneiss inclusions, perhaps with some limestone, were assimilated by the molten syenite.

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THE USE OF THE STEREOGRAM IN PALEOBIOLOGY

BY GEORGE H. HUDSON

The earliest form of the stereoscope was devised by Sir Charles Wheatstone to illustrate the phemomena of binocular vision. This instrument was made known in 1838 and very simple line stereograms were drawn to accompany it. By a curious coincidence Daguerre succeeded in perfecting his photographic process during the same year and thus opened the way to the production of stereograms which would possess something more than a purely theoretical interest. Thus the stereoscope and the rather bulky and clumsy form of mounted stereogram developed together and the former became specialized or adapted for use with the latter only.

In these days of cheap and excellent methods of reproducing photographs there is no valid reason why stereograms should not be printed and bound together with descriptive text in book form. This would only be a step in the direction of "scientific management." It would save time now lost in keeping the loose stereograms in order, in finding the one desired and in replacing it after use. It would insure against loss and damage. It would open avenues for use now unfortunately closed. Stereograms could be made to illustrate books of travel, textbooks, scientific papers and popular magazine articles dealing with the world and its workers in all spheres of human activity from the mine to the stage. To open this new field we need only a stereoscope that shall rest on the page while being focused or adjusted.

This article has been prepared to demonstrate the desirability of using stereograms to illustrate scientific papers. The field chosen lies both in biology and paleontology. The illustrations are confined to a few species of sea stars but both recent and fossil forms are represented.

As a temporary makeshift to enable us to see our plates as solids we will use the ordinary Holmes stereoscope in one of the following ways.

Let the observer seat himself before a table arranged to let a good light reach the page from the left side. In front and about ten inches back from the edge of the table place two or three moderately heavy books. Slide the transverse card carrier off the end of the rail of the stereoscope and place this end against the lower edge of the bottom volume. By now placing the forehead against the hood and using a gentle pressure it is easy to hold the instrument at an angle of about forty-five degrees and at the same time look through the lenses. Both hands are free to bring any stereogram into proper position and focus. The line separating the two views must be kept near the center of the rail and the lower edge of the stereogram kept parallel with the horizontal edges of the lenses.

This end may also be attained by placing the stereogram with its lower edge close to the edge of the table and holding it as nearly flat as possible with proper weights. Then hold the rail of the stereoscope vertically against the edge of the table and move up or down to focus.

For a quickly made but more permanent device, procure two pieces of board, one 10 inches x 12 inches x $\frac{7}{8}$ inch and the other 2 inches x 1 inch x $\frac{7}{8}$ inch. Fasten the smaller piece under the middle of one of the 10 inch edges, keeping the two $\frac{7}{8}$ inch faces flush with each other. A simple clamp will hold the rail of the stereoscope against this $1\frac{3}{4}$ inch face. Two or more elastic bands around the board will hold the volume to the stage and both hands may be left free for other work.

Still more desirable would be a large inclined stage with spring clips and a stereoscope body that could be focused by means of a rack and pinion as in a binocular microscope. A cheap and convenient form could be modified after Brewsters "box" stereoscope in which the loaded base of the instrument should rest directly on the printed page.

If the reader will seek through one or another of the means here suggested to view these stereograms serially and in relief he will realize that the advantages secured are of sufficient importance to warrant the use of this means of illustrating scientific papers.

In order to avoid unnecessary turning of leaves and consequent readjustments, the matter especially referring to each of the following plates has been printed on the page facing it.

Plate 1 Palaeaster parviusculus Billings x 9.5 dia. Canadian Nat. & Geologist, v. 5, no. 1, page 69 (Feb. 1860). From lower Arisaig series. Arisaig, Nova Scotia. The unique holotype in McGill College collection no. 1586

View first without stereoscope and note the white patches over interradius (*a*) and along the margins of arms (*B*) and (*C*). On viewing stereoscopically these are seen to be thin shells of calcite belonging to the surface of the oral ossicles and not yet completely removed from the mold. A perfect cast might show this loss from plate surfaces but the clear delimitation, here so easily made manifest by the difference in reflective power, would be absent.

These figures viewed without the stereoscope may present the appearance of either a mold or a cast, thus adding to the difficulty in interpretation. In both items the advantages of the stereogram are very pronounced.

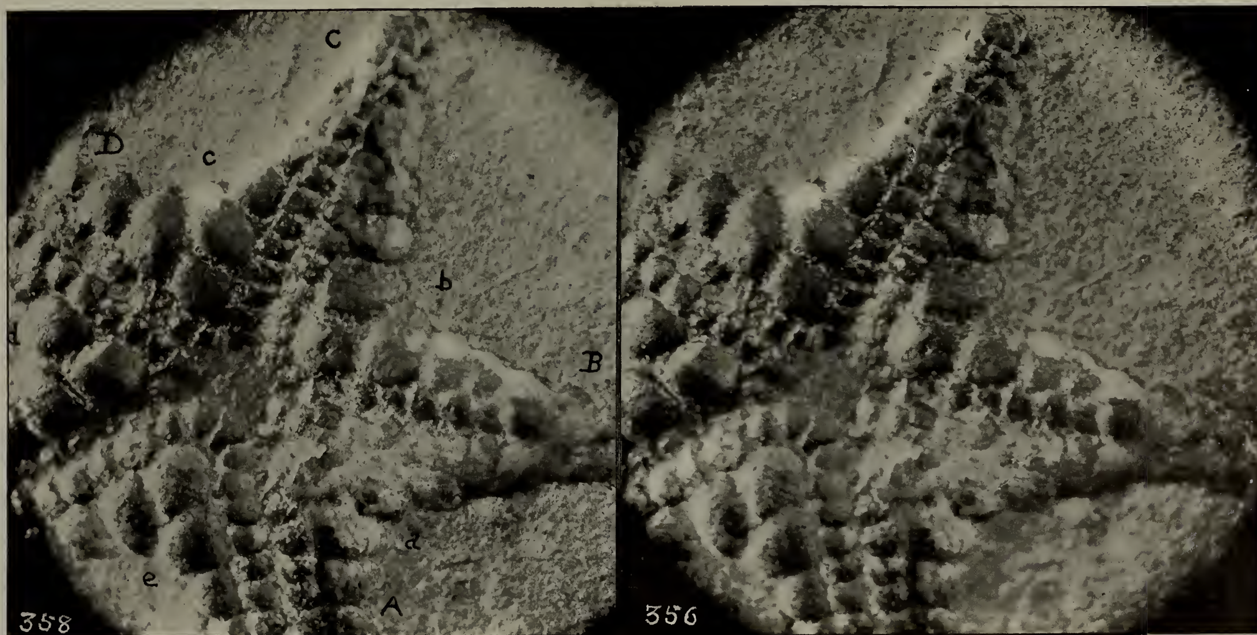

C
D
c
b
B
d
e
A
358
356

Plate 2 P a l a e a s t e r p a r v i u s c u l u s Billings x 9.5 dia.

From a wax squeeze

A squeeze is subject to certain serious defects. The mold may retain some imprisoned air or other fluid. The fluid that escapes from the mold under pressure may make deep folds or distorted channels in the plastic medium used. This medium must also flow out from under the place of greatest pressure and when any two portions of a stream meet in the lee of a projection they can not wholly obliterate the traces of the fold so produced.

In this squeeze one of the marginals, in interradius (*c*) is made to appear as three very distinct but irregular ossicles. Of minor prominence are the folds crossing the lower marginals and adambulacrals of arm (*A*). Still more minute are the numerous lines of flow leaving interradius (*e*) and radius (*E*).

In the Victoria Memorial Museum at Ottawa is a plaster cast of this species showing several adambulacra with central depressions suggestive of those shown in our plate 5, but caused by bubbles of air imprisoned in the deepest recesses of the mold.

The artifacts here enumerated are manifestly absent from the stereogram.

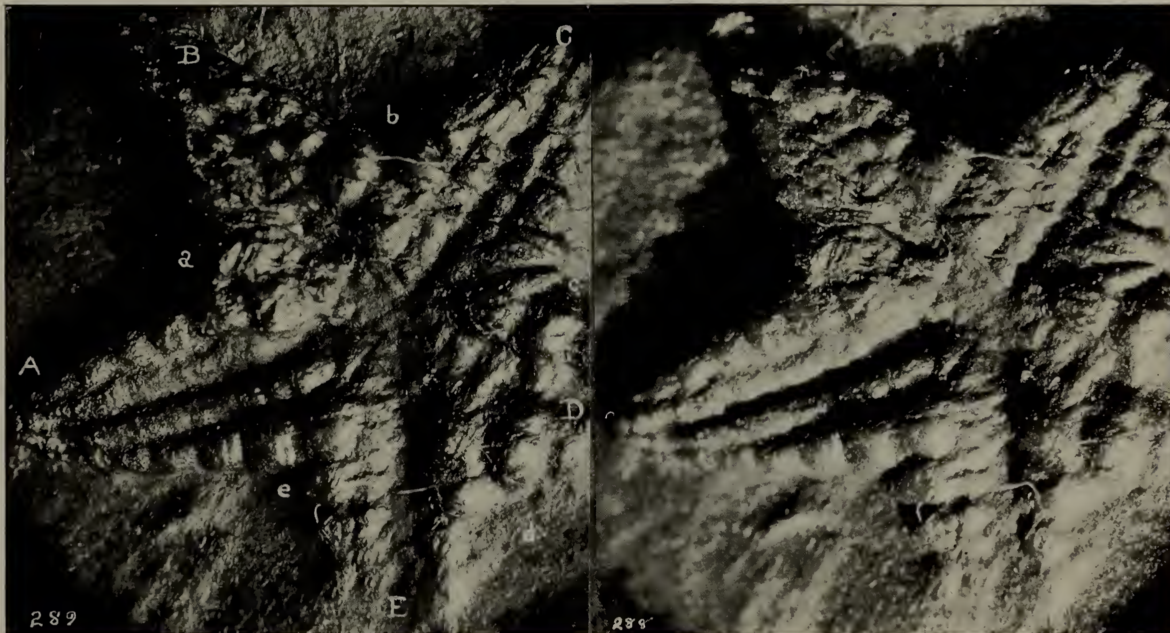

A
B
C
D
E
a
b
c
d
e
289
288

Plate 3 Palaeaster parviusculus Billings x 9.5 dia. From two negatives showing more of the detail of arm *A*. The left view has here been mounted as the right and vice versa, giving closely the appearance of a cast.

In interradius (*e*) note the flat oral surfaces of the pair of adambulacrals forming the " jaw " and their decided inclination toward the interior.

In arm (*A*), lower row of adambulacrals, note the elevated positions of the 3d, 7th, 9th and 11th; in arm (*B*) left row the 9th and in right row the 6th, 7th and 8th. Note also the cases of marked depression. This is evidence for a muscular system that could raise or lower individual adambulacra.

The oral faces of both marginals and adambulacrals seem to be minutely tuberculated and the marginals in places appear to show traces of recumbent small spines. The condition of the surface of the mold must be clearly understood, however, before definite conclusions are drawn.

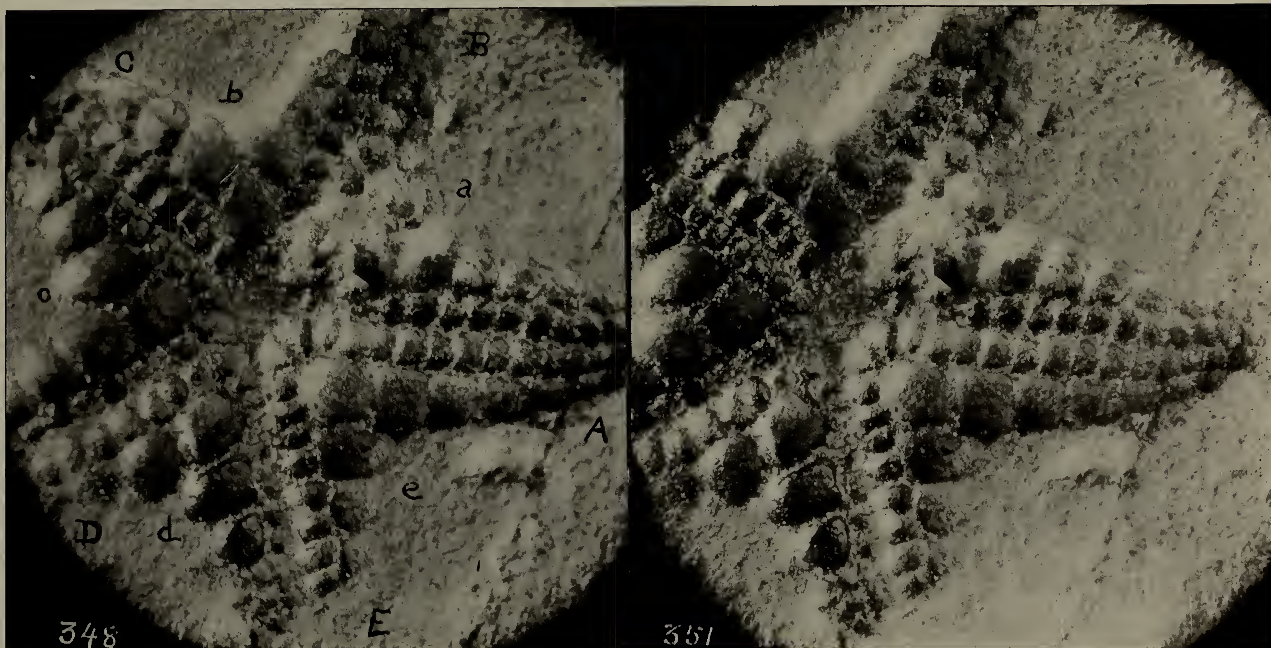

C
b
B
a
c
A
e
D
d
E
348
351

Plate 4 P a l á e a s t e r p a r v i u s c u l u s Billings x 9.5 dia. Photographed under gum damar.

In order to secure a still better representation of the plate surfaces the thin shells of calcite were rendered transparent by mounting with gum damar. The remains of a blackened integument covering the oral surface and slightly descending between the ossicles, as folds, is here made manifest. Plate boundaries are now more clearly defined.

Note that where the adambulacra are in opposite positions, as in the outer portion of arm (*B*), they leave a single medial row of small diamond-shaped openings. Where they are placed alternately they meet those of the opposite row still more closely and the diamond-shaped openings are closed. If this species possessed true ambulacra they were completely hidden in this closed condition of the arm. It is evident that individual adambulacra were permitted a small radial motion, orad or aborad.

With the mold itself for study, Mr Billings made out " twelve or fourteen " adambulacra " in each row." Plate 3, arm *A*, shows sixteen. He wrote, " and they seem to be continued round the edge of the oral plates." We need express no doubt about this. We are also enabled by these new methods to note many other interesting details that Mr Billings could not see with the specimen itself in hand. For his purpose these stereograms would have served better than the type.

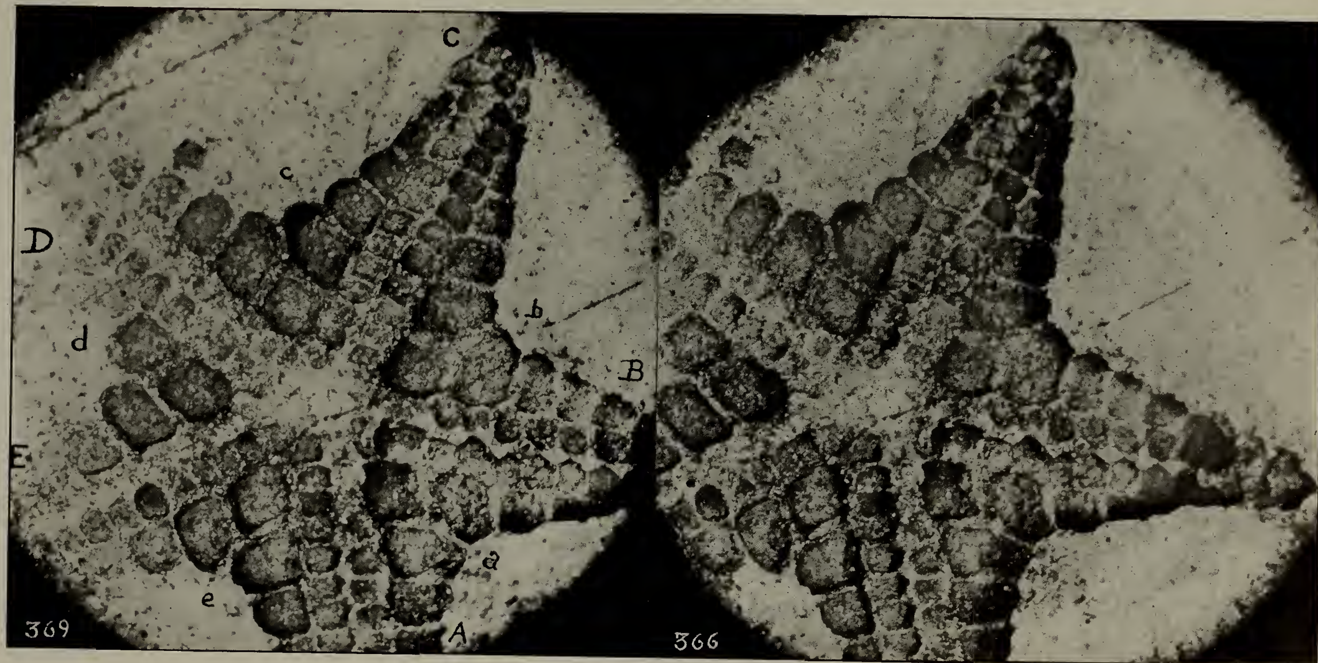

C
c
D
b
d
B
E
a
e
369
A
366

Plate 5 Protopalaeaster narrawayi Hudson. x 10 dia. Photographed under gum damar. Ottawa Naturalist, volume 26, pages 21–26, 45–52. May, June, July, 1912. Lower part of Black River limestone, Ottawa, Can. Holotype in private collection of Mr J. E. Narraway, Ottawa.

Note the "covering plates" of arm IV. These are continued around and partly over the single interradial marginals as shown in interradii 3 and 4. Under each interradial pair, a pair of peculiar plates ("secondary jaws") are seen in position in interradii 2 and 5 and displaced in interradius 1. Under these again are single, apparently crescent-shaped ossicles which appear to have been attached either to a secondary jaw or to an interradial pair of adambulacra (see interradius 1). In interradius 1 the crescent-shaped ossicle appears to be connected with a portion of an aboral covering consisting of some fifteen or more minute ossicles having a diameter of about 0.1 mm each. Note the flat or bevelled surfaces of the pairs of adambulacra forming the jaws in interradii 1 and 2 and the slope toward the mouth precisely as in P. parviusculus. Three ossicles with others now lost were thrust over this specimen from interradius (4) as is shown by the displacement of the two 3d covering pieces in arm IV, the interradial covering pieces in interradius 4 and the displaced pair of "secondary jaws" and oral in interradius 1.

The stereogram not only gives us an impression of depth but it may enable us to make very accurate measurements of the third dimension. In plate 5 a mote of dust settled on the cover glass over the fifth adambulacral of the lower row in arm V. The light reflected by this mote makes it appear as a white speck. As seen in the left view this speck lies between the fifth and sixth adambulacra; as seen in the right view it lies near the inner point of the fifth adambulacrum. The parallax is easily measured and with the angle of view known, here about 18°, the distance from the visible surface of the cover glass to the adambulacrum is easily computed. With a few depths known, the others are easily estimated. The greatest depth shown in this plate is 1.5 mm.

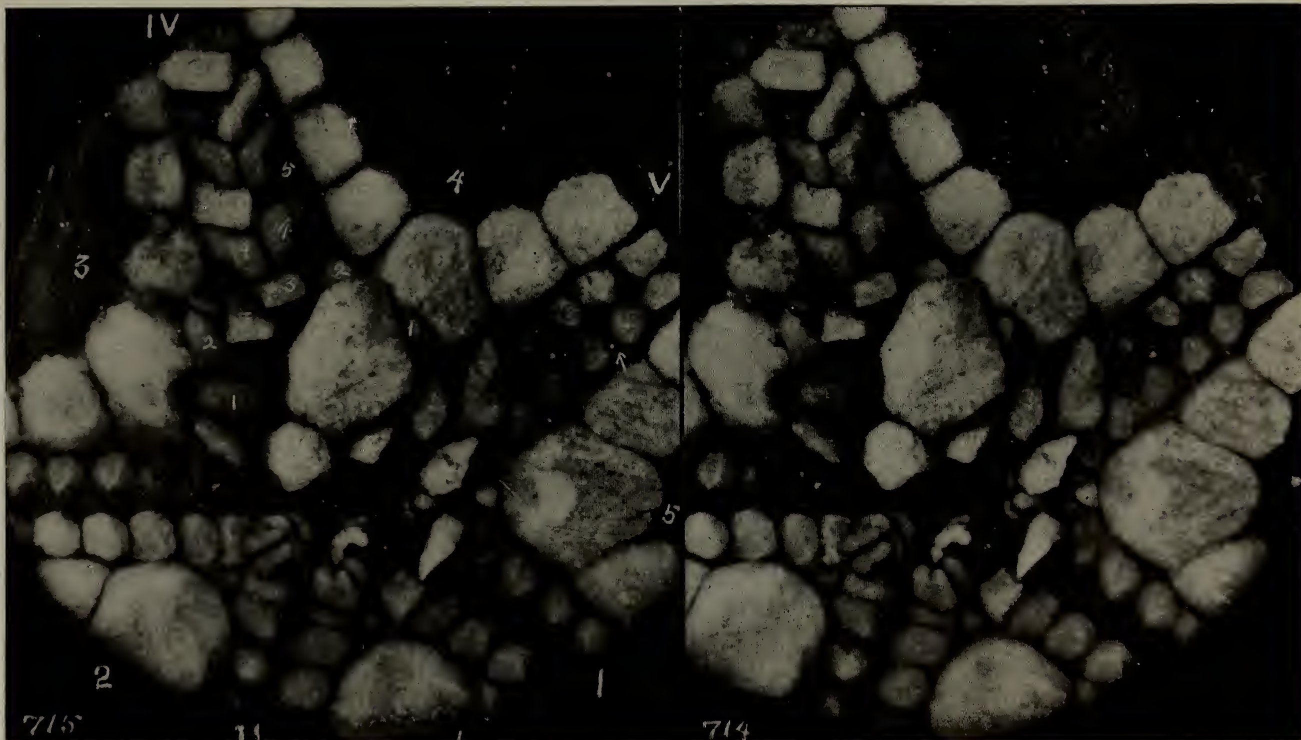

IV
V
3
4
2
1
5
715
714

Plate 6 Benthopecten simplex Perrier, oral aspect x 10 dia. West Indies, 1323 fathoms. Specimen from Museum of Comparative Zoology, Cambridge.

This specimen was loaned by Dr Hubert Lyman Clark, who called attention to its apparent close generic similarity to P. narrawayi. This plate and the two which follow it are here presented to emphasize, first, the need and value of more careful comparison of ancient and recent forms of life; second, to show that published stereograms may be made to foster such study; and third, to illustrate certain advantages of the gum damar mounting. As the fossil forms ought to have a message for students of recent material and the recent forms a message also for paleobiologists, no special argument is here needed to support the first proposition. For the second, compactness; ease of comparison; freedom from effort to assemble rare and scattered types; saving of time; saving of rare specimens themselves from loss or damage; possibility of reconstruction by models of forms after loss by fire, or accident; and the truthfulness of the stereogram itself, should be sufficient recommendation. To appreciate the changes produced by the damar mounting, this plate should be carefully compared with the next.


A
B
a
b
C
c
D
d
E
e
505
506

Plate 7 Benthopecten simplex Perrier, oral aspect under gum x 10 dia.

We have here lost the outer light reflecting surface of minute granules, and have rendered transparent a thin outer layer of the ossicles and of some of the tissues associated with them. Portions of the preserved softer parts, here seats of muscular activity, are rendered in black. Three kinds of tissue seem to be clearly differentiated, that of the ossicles, a ligament like tissue connecting an adambulacrum with its neighbors in the same row, and a scattered muscular system of fine separate fibers.

At the end of arm *E* an adambulacral has been removed and we see a pit in the articulating surface of an ambulacral, filled with fine black fibers. That the adambulacrals possessed corresponding pits is revealed by the darkening of the plate centers which shows them to have been thinner in this portion. The mouth plates are formed by the interradial pairs of adambulacra but to the orad edge of each there appears to be fused an additional piece. These fused pieces are suggestive of the peristomial covering plates of Protopalaeaster narrawayi. An orad may be seen under the first pair (parted mouth plates) of adambulacra in interradius (*b*). A portion of a dark but almost transparent radial canal is seen in arm *E*.

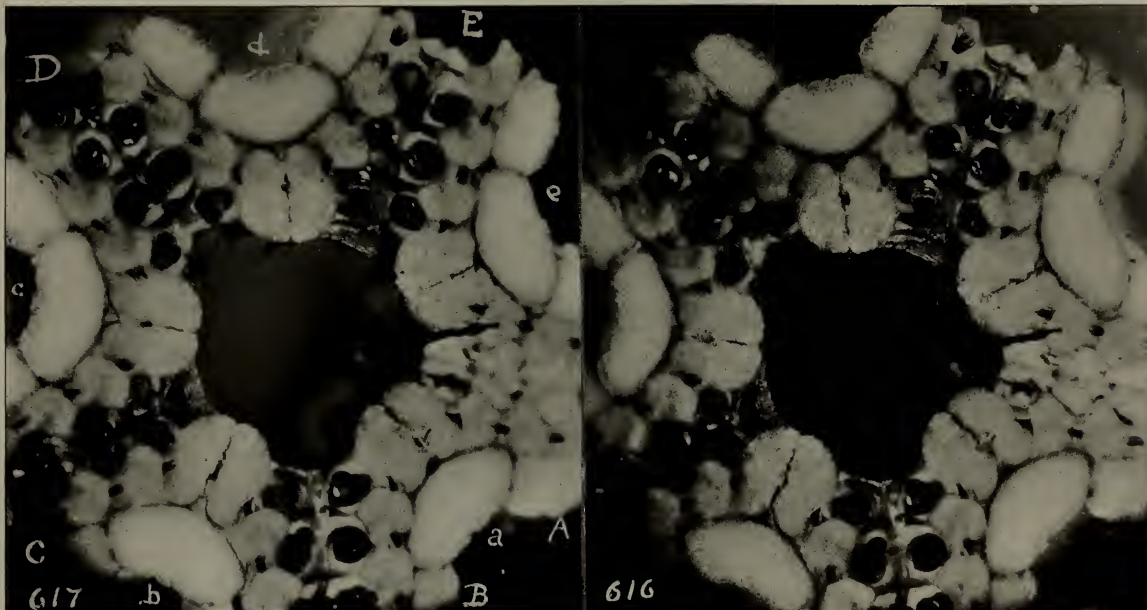

D
d
E
e
c
C
617
b
a
A
B
616

Plate 8 B e n t h o p e c t e n s i m p l e x Perrier, oral plates from aboral aspect, under gum x 10 dia.

In interradius (*d*) are seen a pair of ambulacral plates, which are inclined orad as if to support the fused distal pieces of the jaw plates, but which also have one shoulder recurved or arched to pass beyond the edge of the oral and support a proximal piece (first adambulacral) of the jaw plate. These first ambulacral plates do not meet their neighbors across the furrow but each is supported by a shoulder on the oral side of a second ambulacral. Each ambulacral, however, supports not only its own ambulacral but it also sends a small shoulder orad to in part support the next adambulacral. The strong ambulacra and weaker adambulacra both rest against the flattened inner wall of the marginals. Were the arms in a more contracted or closed position the oral aspect of this species would present a medial row of diamond-shaped openings for each arm and if P a l a e a s t e r p a r v i u s c u l u s possessed ambulacra, its oral skeleton must have been remarkably like that of Benthopecten.

The added transparency secured by the gum process is very manifest in working with fossils. Aside from the effects secured in plate 4, we should also note the transparant surfaces of the ossicles in plate 5, interradii 4 and 5. Buried black grains may be detected to a depth of at least 0.1 mm.

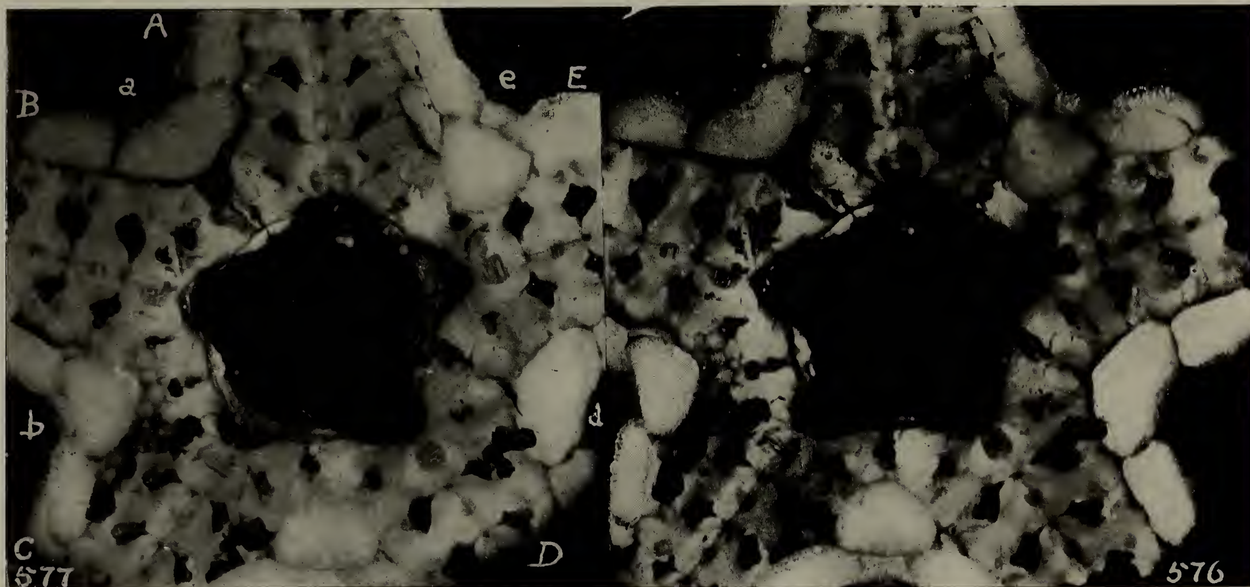

A
a
B
e
E
b
d
C
577
D
576

Plate 9 Palaeaster niagarensis Hall.

Detail of oral surface of disk under gum x 9.5. Paleontology of New York. Volume 2, pages 247–48, plate 51, figures 21–23. Cornell University collection, no. 7331. Niagaran. In the shale at Lockport, N. Y.

Pointing orad from the big marginal in interradius 4 is a dark, flattened spine that evidently was one of a pair which met each other with a straight inner edge. The " mouth plate " so formed was longer and more acute at tip than in Benthopecten simplex. These pieces can hardly have been highly modified adambulacra but they are remarkably like the pair of " covering pieces " which were seen in Protopalaeaster narrawayi (plate 5, interradius 3). The attachment to the marginal seems to have been made by means of a granular flexible base allowing much freedom of movement. A second piece with its attachment carried away is present in interradius 2. The surface ornamentation of these pieces enables us to recognize fragments of others.

In radius III we may note two spines with widened bases that appear to have been supported by the sides of the interradial marginals and are still in position to cover the furrow.

The area exposed has evidently lost much valuable detail through the first crude efforts to " clean " this region. A careful development may still yield evidence of value, but the stereogram should be used to preserve all features it may be found necessary to remove.

For transparent effects from the gum mounting study the big marginals in interradii 2, 3 and 4.


1
5
V
258
4
IV
3
253

Plate 10 Palaeaster niagaraensis Hall. Detail of the proximal portion of arm III oral aspect under gum x 19 dia.

Note the transparency of the inner portions of the marginal marked (2); the parallelism of fine elongated white flecks over arm at lower left of the plate; the three pointed depressions in upper left of medial line, which may be artifacts; the larger spines in lower half; the border of black fragments around the inner edges of and between the marginals marked (1) and (2); and the medial double row of small spinelets arranged in combs containing some seven or eight each.

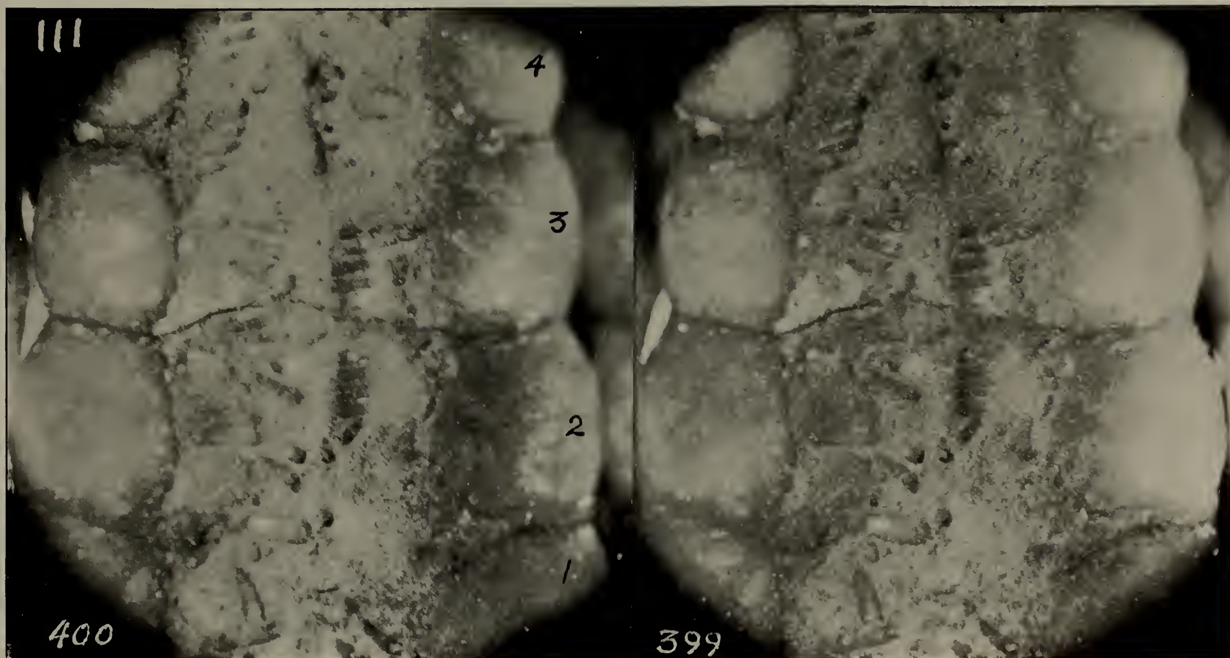

111
4
3
2
1
400
399

Plate 11 Benthopecten spinosus Verrill. Oral view of proximal end of radius IV x 10 dia. Off Delaware, 1186 fms. Museum of Comparative Zoology, Cambridge.

Here again we have evidence for ease and value of comparison of living with fossil forms. According to Professor Schuchert's time table,[1] P. niagarensis lived about 22,000,000 years ago, yet the furrow combs of the present B. spinosus are almost identical in number of spinelets (6 and 7), length, position on the adambulacra, mode of attachment and manner of carrying. In P. niagarensis the spinelets were more slender. The feeding habits were doubtless similar and the specialization through adaption already wonderfully perfect, even in that remote period.

It sometimes happens that a defect in a negative, print, or plate, may introduce a feature or so modify some line, or shading, as to lead to an erroneous interpretation. For instance in the left half of plate 5, interradius 5, the large marginal bears a line due to a scratch received by the photograph after mounting. This is nearly parallel with the lines in the ossicle itself. Its absence from the right-hand half shows it to be an artifact. Two different negatives taken at different angles would hardly introduce errors twice in the same place and could never so introduce them as to produce perfect stereoscopic relief. The very presence of such relief is positive evidence that we are dealing with a true feature of the specimen.

[1] Paleogeography of North America, plate 101.

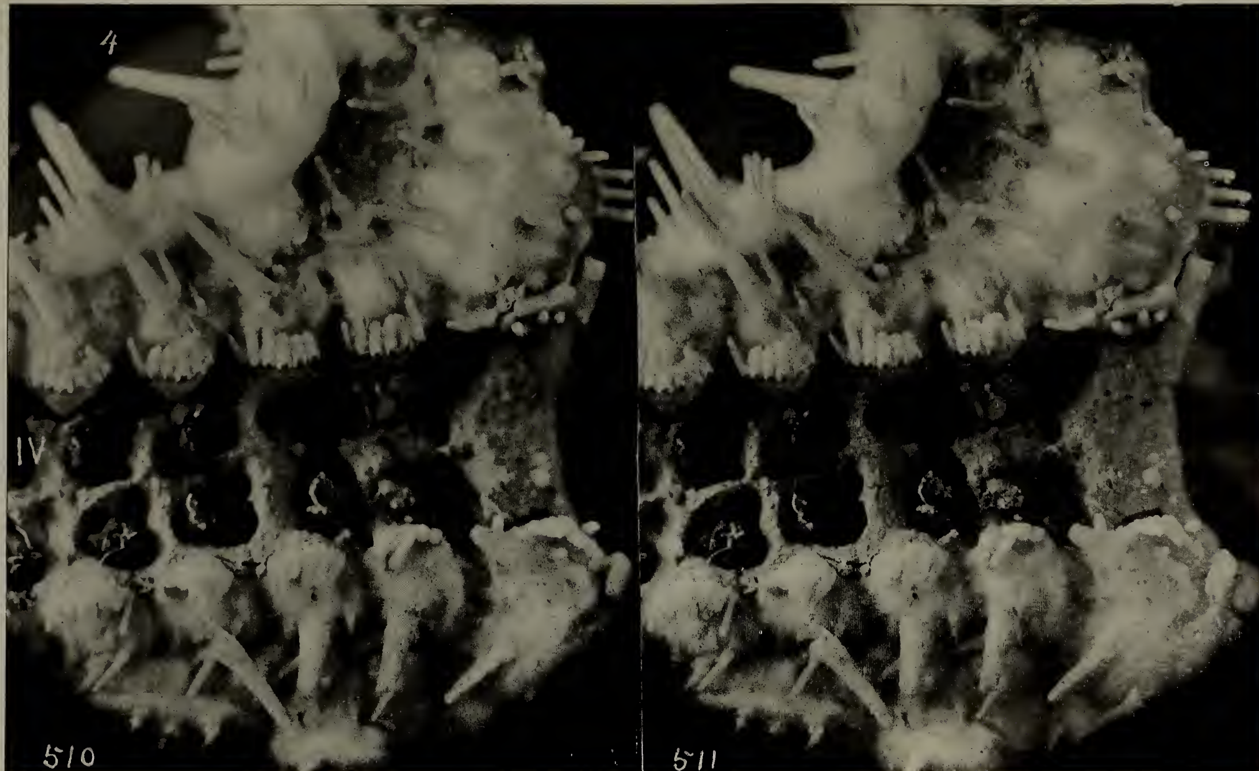

4
IV
510
511

Plate 12 Palaeaster niagarensis Hall. Detail, oral aspect of arm V under gum x 19 dia. The adambulacra and the manner of attachment of the furrow combs are here well shown.

As a matter of interest and for the benefit of the art of illustration, we ought to compare this stereogram with Hall's figures 22 and 23 (op. cit.). The plates of Hall's report were beautifully drawn and the lithographic work was of very high character. It is the writer's desire, however, to point out that the best drawings ever made will neither reveal all the artist saw, nor will they reveal anything he did not see. The drawing also emphasizes certain features at the expense of others. On the other hand, the stereogram reproduced without retouching may be made to present all that can possibly be seen and (by modern methods) much that could never be seen otherwise. For example, in Hall's figure 22 the combs have five spinelets only and they are attached to the marginals and project over the furrow. In this stereogram the combs are seen to have seven or eight spinelets, and they are attached to the inner edge of the adambulacra and project away from the furrow.

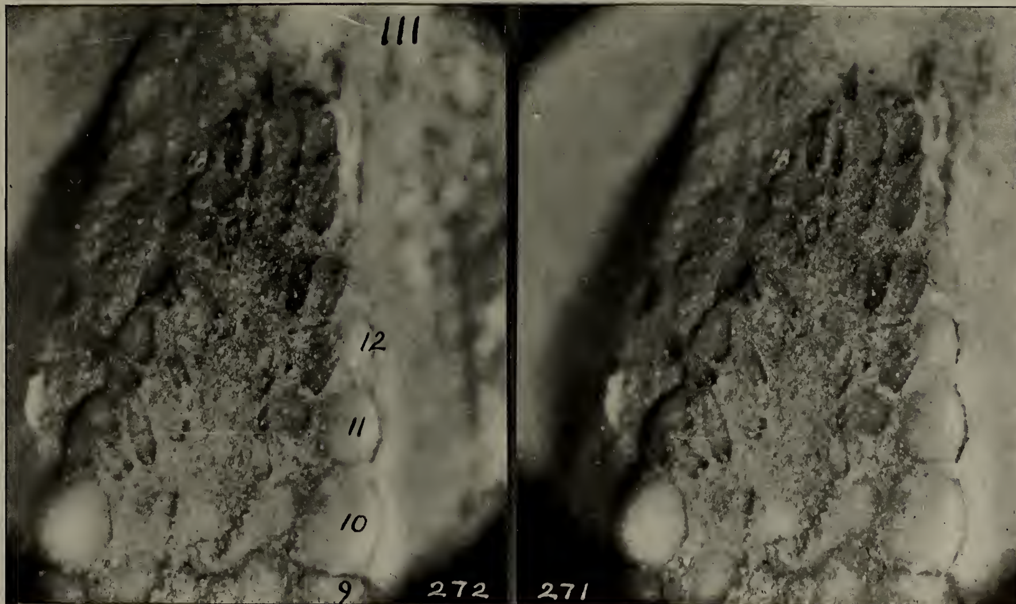
In these stereograms the author has been enabled to present some items he has seen but they are not distorted to make others see them *from his personal standpoint*. In the same stereograms also there is much that the author has not seen, but which may yet be recognized and found to be of value a hundred years or more hence. Can any form of illustration have a higher, truer or more lasting value?


V
6
5
4
242
241

Plate 13 Palaeaster niagarensis Hall. Detail of oral surface of arm III under gum, x 19 dia. It is evident from this stereogram that, in addition to the furrow combs, each adambulacral bore also two larger spines.

The stereograms illustrating P. niagarensis were slected from over forty made of this species. The numbers on the lower edge of the separate halves are the numbers borne by the separate negatives. Those who have kindly loaned material for study have had stereograms sent them and one writes, "I would rather have the stereogram than the specimen." If the type is a mold and therefore useless for development, a good stereogram ought to answer every purpose. The publication of such would therefore tend to render unnecessary the future loans of rare types and at the same time practically bring those types to the laboratories of thousands of students.

In closing I may call attention to the possibilities of penetrating the stone by invisible light waves and so revealing the entire specimen in stereoscopic relief, viewing as it were a transparent ghost of the species with various details of its internal structure. For example, I refer to the successful work of M. Pierre Goby of Grasse, France, in using the microscope in conjunction with such light, notice of which appeared in the Literary Digest, November 16, 1912, page 900. This subject is well worth the attention of paleobiologists.


111
12
11
10
9
272
271

THE ORIGIN OF THE GULF OF ST LAWRENCE[1]

BY JOHN M. CLARKE

Present-day geography contemplates not only the surface of the earth and its forms of land and water, but considers also the physical and human causes that are modifying it. The geographer sees these things and looks forward; the geologist sees present conditions and looks backward for their inception — and then again forward in the perspective of cause and effect. It is hard to draw the line between these two fields of scientific interest. Some have tried to circumscribe each but it is a bootless effort. Each trenches on the other. At all events every geographer is something of a geologist. And this may be my justification in endeavoring here to find a clue to the origin of a geographic feature of so deep interest to us all as the Gulf of St Lawrence. We are very apt to take such a geographic fact for granted as it is and to let our geography end with a knowledge of its outlines, the contours of its shores and its bottoms. To unravel its history and to find the causes which have brought it into being is a task that will be fruitless on the face of the facts as they present themselves to the maker of charts. The key lies in the geological birth and growth of the whole land mass by which such a body of water is embraced.

So to find the real factors in the making of this classical and romantic body of water, we shall have to go well back to the early events in the making of the land.

Fundamental among these facts is the existence of the great mass of crystalline rocks that sweeps from Labrador to the Laurentides and northwestward to Alaska — the Canadian shield — as a continental land mass rising above the waters of the primitive ocean. Its shores were washed by the first sea whose life records have been kept for us in the sediments which, now changed to shale, sandstone and limestone, bound all its ancient shores. On the south coast of this Canadian continent, in the ages of its independent existence, lay, in the longitude of Montreal, a great tongue or peninsula which forms the Adirondack mountains of New York; and still farther south, perhaps, were long and narrow land masses that kept their uncertain heads above water for no great time. About these con-

[1] Reprinted from Bulletin de la Sociètè de Géographie de Québec, v. 7. January 1913.

tinental and insular shores and on the bottom of these shallow intervening seas were laid down, to hundreds and even thousands of feet, the sediments of the ocean filled with the remains of living beings that played out their days in succession as unknown time rolled by. Thus the shallow sea became overloaded with its burden of deposits — a load of soft and plastic material made still more yielding by being carried constantly farther downward into regions of higher heat as the later deposits continued to pile on top of the earlier. Against this soft and weakened mass of deposits stood, on one side, the great weight of the waters in the vast Atlantic ocean basin, pressing upon them landward, and on the other, the irresistible crystalline continent — the Canadian shield.

The outcome was inevitable; the whole mass of sea deposits was slowly turned up into great mountain folds and troughs — not all at once but slowly, fold after fold, to unmeasured heights, and often the folds at the south were thrust upon and over folds at the north. Thus, broadly and rapidly speaking, the Appalachian system of mountains was built up through the ages, not at any one time in geological history, but beginning slowly and early at the north and ending late at the south. In the early development of this structure the shove of the soft rocks against the crystalline shield was so valiantly withstood at the north, that there, along the southern outline of that shield, from Lake Ontario to Natashkwan, the softer rocks broke down, making, where the two lay in contact, a deep and broad fracture extending from southwest to northeast. The existence of this break or fault in the rocks was long ago signalized by Sir William Logan[1] and it is known today as " Logan's

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[1] One who has followed closely in the footsteps of Sir William Logan in his geological work in eastern Quebec may perhaps be permitted, without impropriety, to revert to the extraordinary achievements of this great Canadian, and his distinguished services to geological science.

The year after Sir William organized the Geological Survey of Canada, he began his official career by explorations in the Gaspé peninsula. Laboring in the early 40's among the picturesque sea cliffs of that inviting country, traversing its wildernesses, he determined its geological systems with their wealth of unrecorded facts and made of the Gaspé country ground that will always be of classic worth to geological science. Had he done no more, he would have served well; but he did do vastly more in the development of the mineral resources of the Dominion. A country that is rich and strong and great will not forget its obligation to such a distinguished servant. France, it is said commemorates by public memorials the services of its eminent civilians more often than it does those of its military and naval heroes. Such a memorial to Logan is wanting. There stands a rock cliff in the heart of the fault." It is beyond doubt the determinant factor in the existence and course of the St Lawrence river. "Logan's fault" gave birth to the river by setting down a line of weakness along whose crushed and broken rock masses the continental waters draining to the sea could find their least obstructed passage; and thus began the oldest of all great rivers of the earth and the oldest of all rivers on the earth of which we have any definite record.

The Appalachians of the Eastern Townships follow the normal northeast-southwest course, but in Gaspé, as every one knows, they swing about into a curve like a swan's neck or the upper line of the letter S. There the northern mountains end at Cape Gaspé on the land but their vanishing point can be followed some fifteen miles off to sea southeast, to the rocky shoal known on the charts as the "American bank." This mountain ridge or orogenic axis at the north is unlike that of the Appalachian ranges at the south. The ridges of these ancient mountains cross Nova Scotia in the normal trend; their southwesterly extension off New England is largely buried beneath the sea, and to the northeast they continue on their course across Newfoundland. Looking at the sketch map adjoining, one sees the different curves of these mountain axes at north and south and between them an area which we must believe was less involved in the profounder or axial movement of these disturbances — the region of central and northern New Brunswick. We are speaking of times and conditions when there was no Gulf of St Lawrence, when the elevation of the mountains had brought, if not quite all, at least most of the land now at the bottom of the gulf, above the water line and the continent extended without break from the present eastern shores out to the islands and across to Newfoundland. For long this ancient coast line was a series of mountain folds between which the ocean waters entered in broad channels southwestward, laying down the deposits of their own time in their due succession. But from the time the most ancient of these mountain folds were made, when the ridges at the north took on their singular curvature, the whole area between their end and the mountain axes to the south became an area of weakness and instability. This sigmoid curve at the north is a factor of profound meaning in the making of the gulf. It seems to be due to

village of Percé, overlooked on one side by towering sea cliffs and on the other by consecrated mountains over which Logan labored in his early work, and here might well be placed a tablet commemorative of the lasting achievements of his great career.

the recoil, as one might say, of the softer rocks in their pressure against the irresistible Canadian shield, so that the line of fracture or fault was deflected at its outer end southward in such a way as

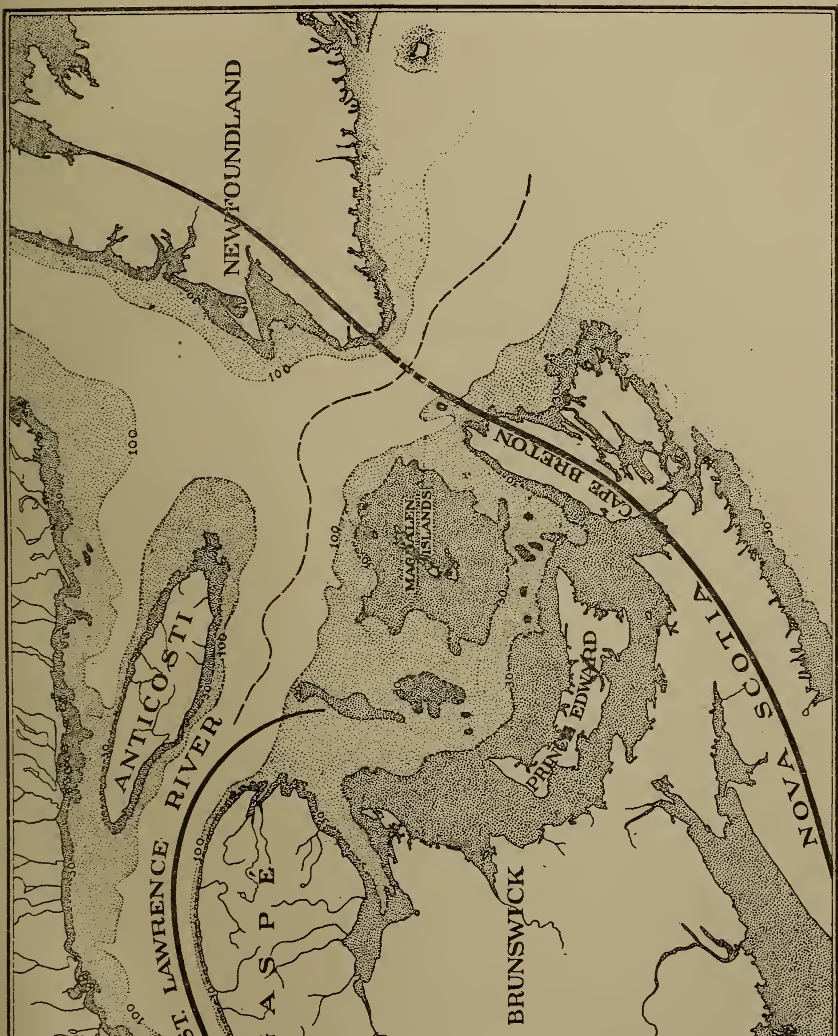

Chart of the Gulf of St Lawrence and adjoining lands

(The areas of the bottom down to 30 and 100 fathoms are indicated by close and coarse stippling. The broken curved line through the gulf is the line of greatest depth. The heavy black lines are the orogenic or mountain axes at north and south.)

to break through the mass of sedimentary deposits. Thus the St Lawrence river has almost of necessity an outer curve that follows the course of the fault and of the folded slate and limestone mountains of Gaspé, while to the north of the fault line and the buried river channel lies the island of Anticosti whose rock strata, full of fossils, lie almost horizontal and were beyond the influence of the mountain making.

This revulsion from the north projected the axial line of resistance southward against the normal course of the other folds and protruded into them a disturbing antagonistic force. The Nova Scotia anticlines were beyond the reach of this projected influence but the folds between were disordered and crosscut and weakened. The picturesquely ragged coast at Percé is due to a complete collapse of a tremendous mountain fold which has vastly deranged the original succession of the rock strata.

The gulf lands had sunk low soon after the mountain-making period was over, and during the succeeding times of the Coal and probably even before, it was chiefly a vast drainage basin receiving fresh land waters with their heavy loads of sediment, then again elevated into a sand desert or great stretches of bars and dunes, and still at times depressed again so that the salt waters came in bringing their characteristic life forms. Then again, in later geological days, after the day of the Coal and the sand bars was over, the region was again elevated into land and the rocks of that land still fringe the gulf shores and make the islands of Prince Edward and the Magdalens.

The submarine course of the St Lawrence river across the gulf is still clearly indicated on the Admiralty charts; from its present mouth southeast it extends, far to the east of Gaspé, east of the Magdalen islands and thence outward to the Atlantic by the passage between Cape Breton island on the west and Newfoundland on the east (Cabot strait). This valley was made when the gulf bottom was land.

The chart accompanying shows the curves of 30 fathoms and 100 fathoms. It is very clear that the deep channel outside the 100 fathom line could not be made by the scouring of the present stream over the rocky bottom of the gulf. A more detailed chart of the gulf would show these depths dropping off from the shore in a succession of stages, or one might say terraces indicative of the gradual and periodical rise of the land bounding the ancient river while the river itself was cutting downward and narrowing its channel as the gulf lands rose. It is not to be conceived that this channel through the gulf is as ancient as the channel between the shores of Gaspé and the Quebec Labrador. The lands which the lower channel cuts are of later birth than those at the north and in its earlier stages we may believe that the river debouched into a shallow sea much as it does today into the gulf. The student of the chart will observe that there is a branch channel leading off in the direction of the Strait of Belle Isle but it is a shallower trough than that to the southeast. The line of deepest water is in the southeast channel and there is a difference in maximums of depth between the two of 155 fathoms, the greatest depth in the northwest trough being 145 fathoms and in the southwest 300 fathoms.

The southeast channel drops quite steeply 1700 feet below the broad 100 fathom plateau and this is twice the depth of the northeast course.

It would seem that the northeast course was a river valley of earlier date than the southern part of the southeast channel, that the river abandoned it for sufficient cause, possibly change in submarine level or blockage by a heavy ice sheet, and then continued to erode its present buried channel to still greater depths.

The courses of existing submarine currents over this region are not yet sufficiently determined to permit us to speak definitely regarding the outpush of the waters through the southeast channel and yet it is practically certain that this is the predominant trend of the major deep water movements of the gulf.

The Gulf of St Lawrence thus owes its existence chiefly to two determinant factors of very ancient date: the breakdown of the rocks which produced "Logan's fault"; and the curvature of the northern orogenic axis which effected a syntaxis or a protrusion of the northern against the southern Appalachian folds. The broken down basin between is a natural and resultant area of rock weakness which has had its short periods of low elevation above the sea, but longer periods of depression.

A NOTABLE TRILOBITE FROM THE PERCÉ ROCK

BY JOHN M. CLARKE

The list of Lower Devonic species occurring in that spectacular cliff L'isle percée or Percé rock, has been given by the writer with some degree of fulness in his volume on the geology of Gaspé (N. Y. State Mus. Memoir 9, part 1, 1908). Among these species several trilobites of interest have been described. These accounts were based upon the collections made during several seasons of diligent work, and subsequent search has not materially added to the census of the fauna. The past summer, however, brought to light two specimens of a commanding Homalonotus, a genus not hitherto recorded from any of the Devonic outcrops in Gaspé county, and not only its presence but the character of the species itself is worthy of note.

The Homalonoti of the boreal Paleozoic regions in America are distinctively characterized by their freedom from dermal overgrowths. They carry no spines or tubercles on any part of the test. This is a statement subject of course to the limitations of our pretty considerable knowledge of the Paleozoic faunas on this continent and while applicable here, it can not be so broadly stated for the boreal Palezoic, particularly Devonic, Homalonoti of the eastern hemisphere. There are European species of which the Siluric H. knighti and the Devonic H. armatus are leading and almost sole examples, whose test is spiniferous or tubercled, while the predominant species are devoid of these growths as in America.

The armate Homalonoti are on the whole quite distinctively austral, especially in their Devonic distribution. Witness of this is the great abundance of H. herscheli Murchison in the South African Lower Devonic[1] and at the same horizon in the Falkland islands.

There is an abundant and often beautifully preserved species in the Lower Devonic shales of São Paulo, Brazil, termed by the writer H. noticus, which is free of spines save for one conspicuously developed on the epistoma, a structure which is present in H. herscheli, but absent in all boreal species.

[1] The large number of species of this genus described by the writers on the South African Devonic has seemed to me not justified by evidence, except for provisional purposes.

The species under present consideration conforms in these structures to other American Homalonoti and is to be directly compared with H. vanuxemi of the New York Helderberg and H. major of the New York Oriskany, accounts of which are to be found in Palaeontology of New York, volume 7. This resemblance is not unexpected in view of the many other affiliations of the Percé and Grande Grève Lower Devonic faunas with those of New York. The Percé Homalonotus is represented by specimens which indicate its large size. The largest known example of H. vanuxemi is a broken individual from Rondout, N. Y., and indicates an animal 280 mm in length, which is almost exactly the proportions of the Percé species. But even so large, these specimens fall far below the dimensions of H. major, the largest of all members of the genus. Yet there are, between these two species, few differences except dimensions, habitat and geologic horizon. In structure they are closely alike, the smaller H. vanuxemi occurring in the Helderberg limestones and lime shales and H. major in the Oriskany silicious limestones. The Percé species is rather better preserved and now better known in its details than either of the New York species mentioned, but its designation must show its affinity to them even at the cost of a multiplex name. I therefore venture so far as to express this relationship by the designation Homalonotus (v.-m.) perceensis.

The structure of the parts is indicated in the drawings which show the pygidium in normal convexity and entire, six of the eleven thoracic segments (all are preserved on a second but somewhat worn example), the head, partly worn away and the hypostoma. The obscurity of segmentation of the pygidium is characteristic and differential from other Devonic species, especially the common middle Devonic H. dekayi. The cephalon of H. vanuxemi-major has not been well made out and the hypostoma of this type is now seen for the first time, both of the Percé specimens showing this organ.

The author has shown the presence of H. vanuxemi in the Lower Devonic Moose River formation of Maine at Matagamon and Moosehead lakes.[1] Until now no representative of the genus has been known from points farther north.

[1] N. Y. State Mus. Mem. 9, v. 2, p. 67.

ILLUSTRATIONS OF THE DEVONIC FOSSILS OF SOUTHERN BRAZIL AND THE FALKLAND ISLANDS

BY JOHN M. CLARKE

Three years ago the writer completed a protracted series of studies on the Devonic faunas of South America, especially those of southern Brazil in the state of São Paulo, and of the Falkland islands, incidentally also of the Cordilleras of western Argentina. These studies were authorized by the director of the Geological Service of Brazil, and the full discussion of these austral faunas is in course of printing as a memoir of that organization. Meanwhile, because of the delays attendant on publication in Brazil, and by permission of the director of the Brazilian Survey, occasion is here taken to present illustrations of the leading species of the Brazilian and Falkland faunas which are with propriety incorporated in this report on account of their intimate but contrasting relations to the Devonic faunas of New York.

While no other purpose is here sought than to set forth, as well as may be by illustration, the distinctive fossil characters of this southern Devonic and the whole estimate of the real significance of the fauna must be reserved for its more complete presentation and discussion, it is well to intimate that these Devonic faunas of the south and of the north, though united by general characters, are keenly and widely separated in the analysis of their specific and superspecific structures. This fact makes itself so clear that it is evident the northern and southern faunas developed in separated basins with but restricted intercommunication during the Devonic. These illustrations also indicate the continuity of the strand line and of the Devonic continents from southern South America to the Falkland islands and thence to South Africa.

EXPLANATIONS OF PLATES

Plate 1

Homalonotus noticus Clarke

(See plate 2)

Fig. 1, 2 Dorsal and profile views of an extended complete individual of mature dimensions. This is essentially an internal cast, showing approximate normal convexity. The epistoma is exposed and the place of the anterior apiculus seen.

Locality: Ponta Grossa, São Paulo. Brazil

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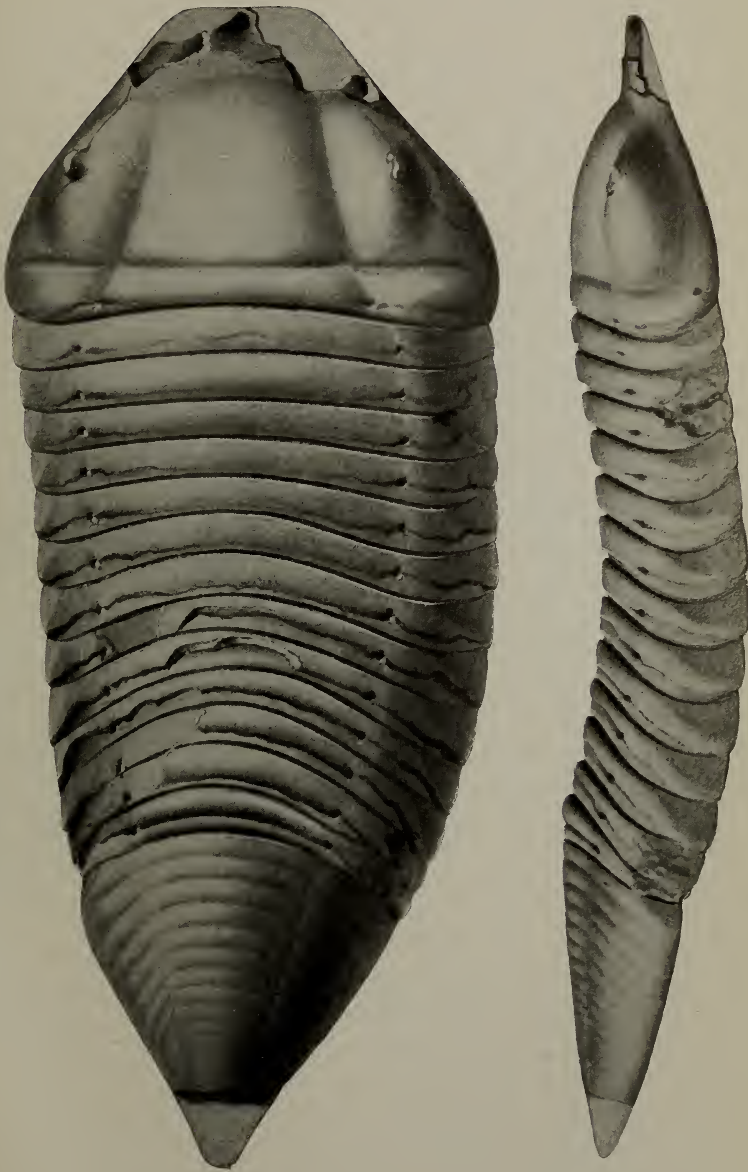

Plate 2

Homalonotus noticus Clarke

(See plate 1)

Fig. 1, 2 Nearly entire small individuals
3 A large cephalon
4 The anterior doublure, epistomal plate and apiculus
5 A head with part of the anterior removed to expose the doublure and epistomal plate
6 An entire cephalon with apiculus
Locality: Ponta Grossa, São Paulo, Brazil

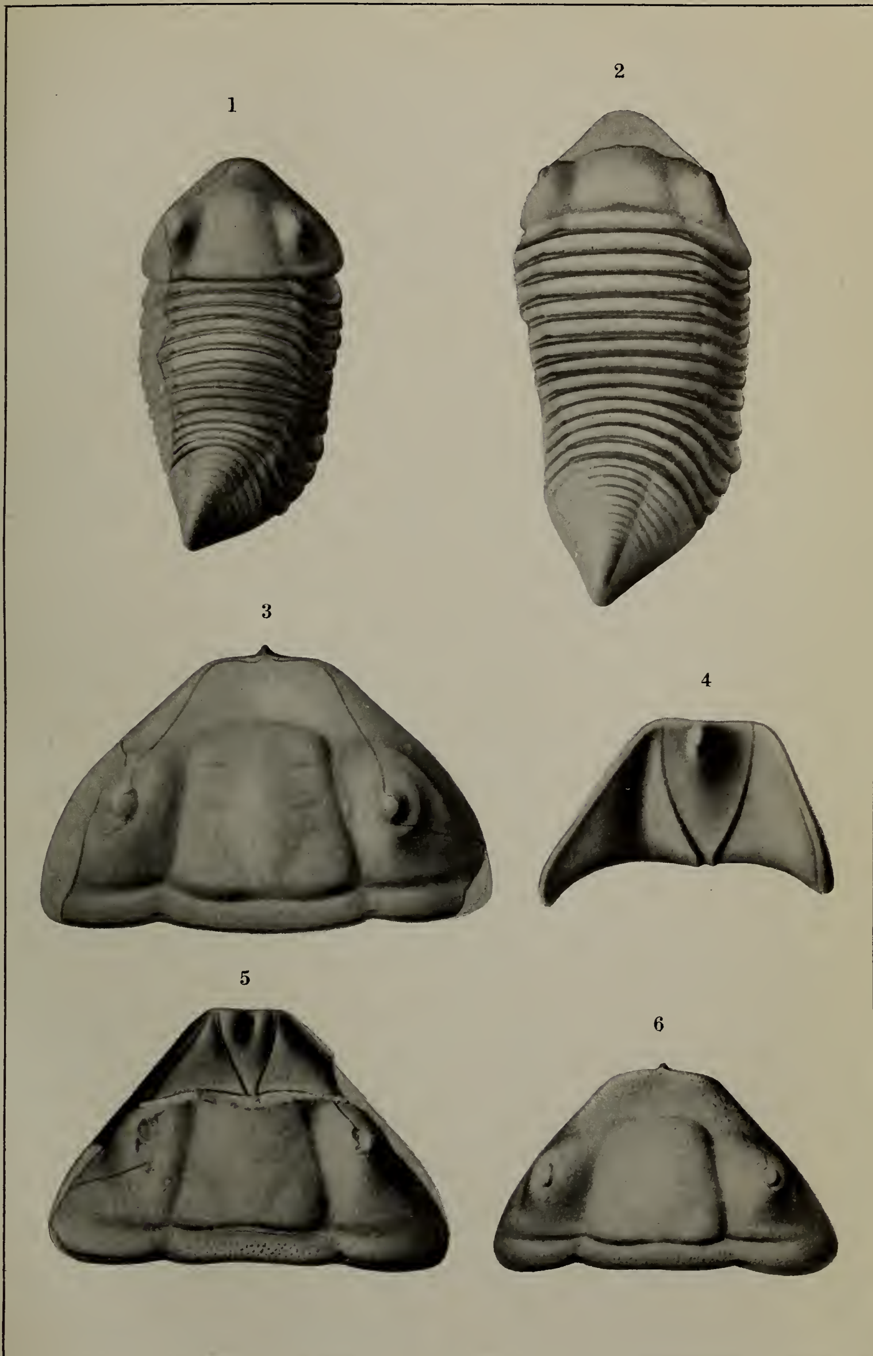
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Plate 3

Homalonotus (Schizopyge) parana Clarke

Fig. 1 Pygidium and a few thoracic segments
2 A pygidium apparently lacking one segment
Locality: Tybagy, São Paulo, Brazil

Homalonotus herscheli Murchison

Fig. 3 A small head with apiculus and scattered tubercles
4 A series of strongly pustulose thoracic segments
5 A pygidium with a few tubercles
6 A large cephalon, nearly entire, of characteristic form, with spinous tubercles at the genal angles and traces of others on the glabella
Locality: the calc-nodules of Pebble island, West Falkland

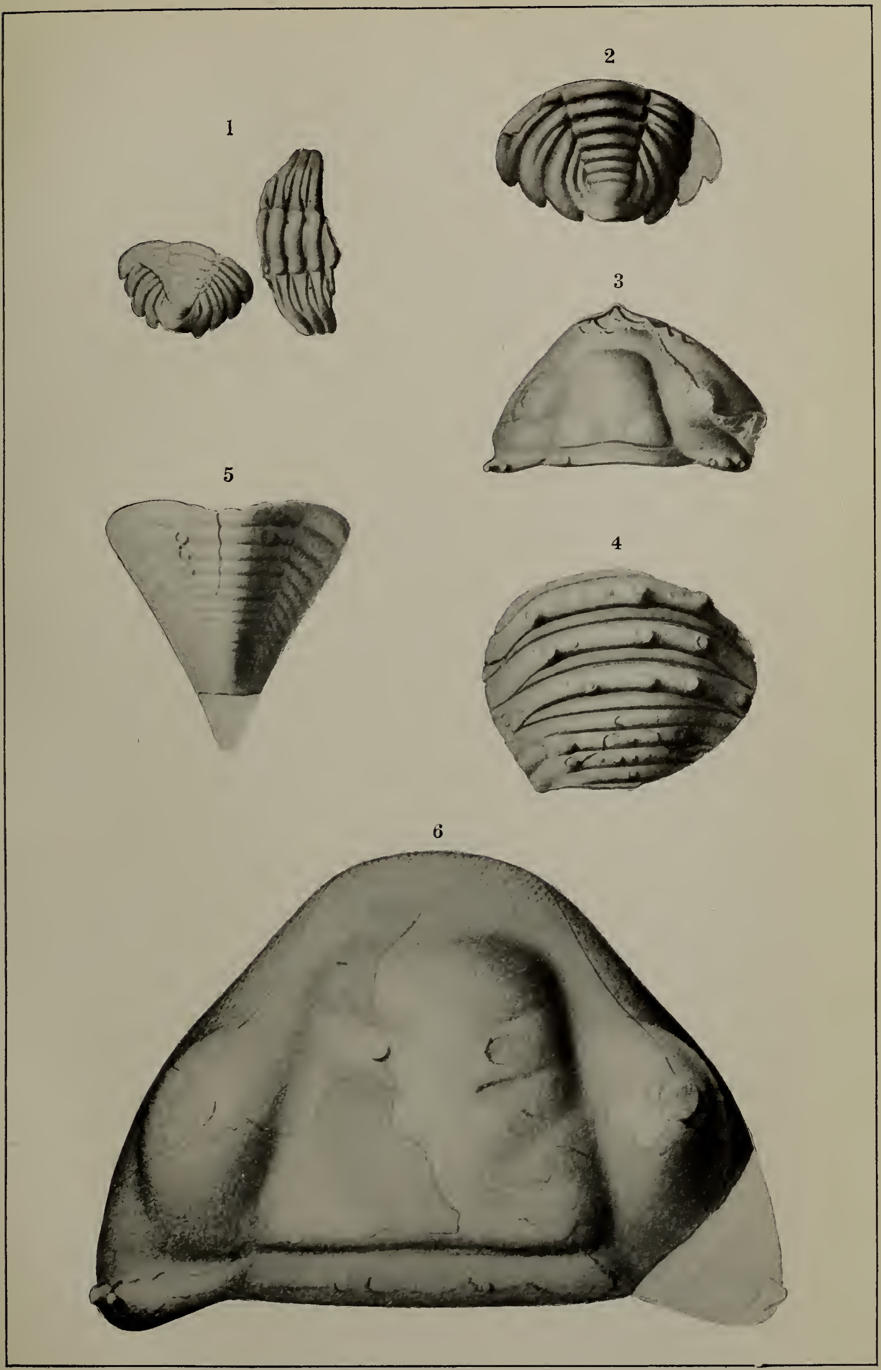
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Plate 4

Dalmanites acacia Schwarz

Fig. 1, 2 Cephala showing the finely granulate surface, small eyes, nuchal spine and slight anterior projection

3, 4 Lateral and dorsal views of thorax and pygidium, showing the length of the erect thoracic spines

Locality: calc-nodules of Pebble island, West Falkland

Dalmanites falklandicus Clarke

Fig. 5 A normal cephalon with large eyes, short cheek spines and coarsely pustulose pygidium

6 Thorax and pygidium of this species

Locality: Fox bay, West Falkland

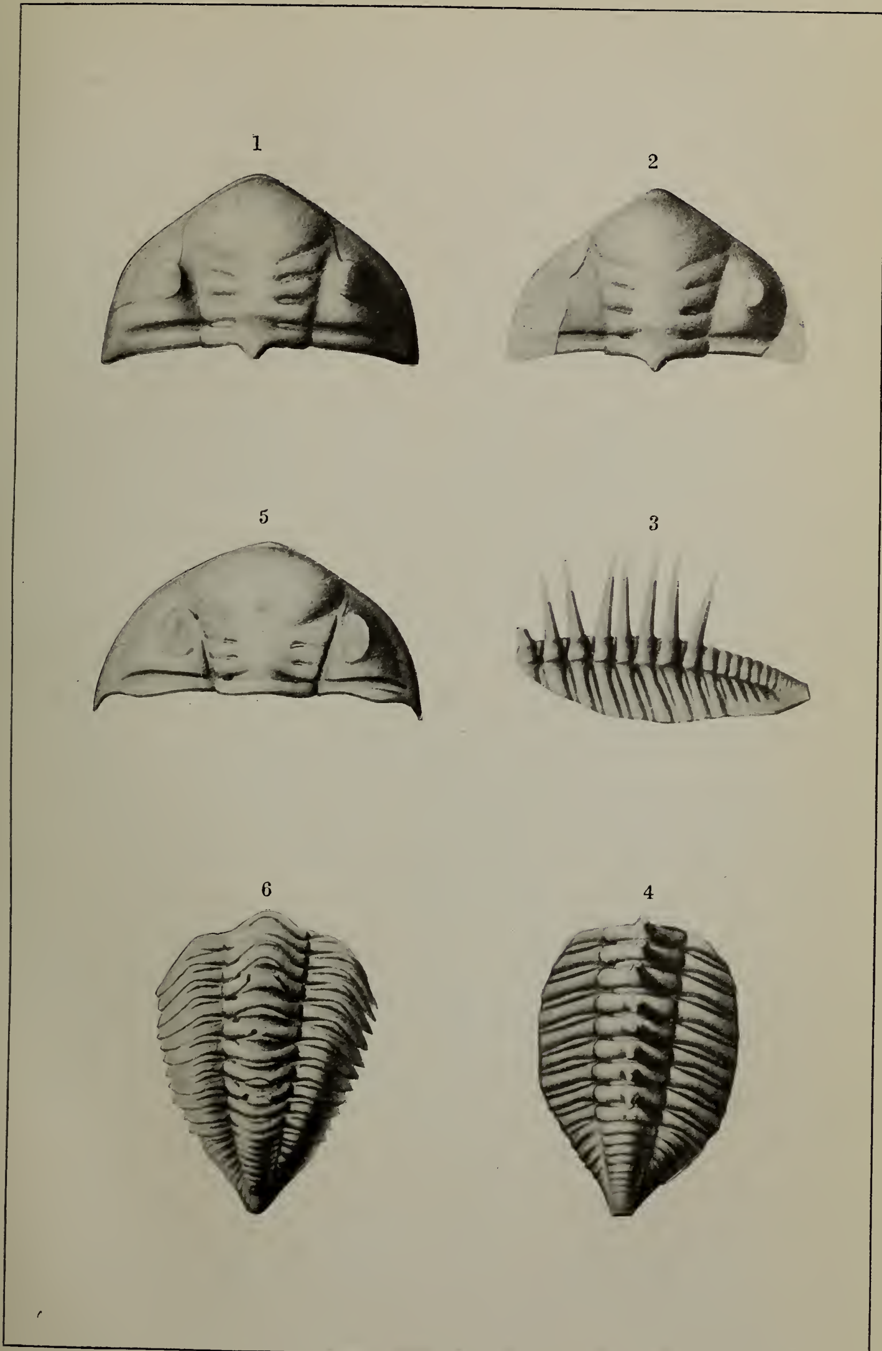
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Plate 5

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Dalmanites accola Clarke

Fig. 1 A nearly complete cephalon
2 A small entire cephalon with long genal spines
3, 4 Pygidia showing the uniform distribution of the pustules
5 An incomplete but undistorted individual with the missing parts restored in outline and showing their mutual proportions, arrangement of the scattered pustules, length of genal spines, size of eyes, etc.
Locality: Ponta Grossa, São Paulo, Brazil

Cryphaeus ? allardyceae Clarke

Fig. 6 A somewhat weathered head and a thorax with pygidium from a calc-nodule. The association of these parts, though found disconnected, seems highly probable in view of their being the only fossils in the nodule and of their agreement in size
Locality: Pebble island, West Falkland

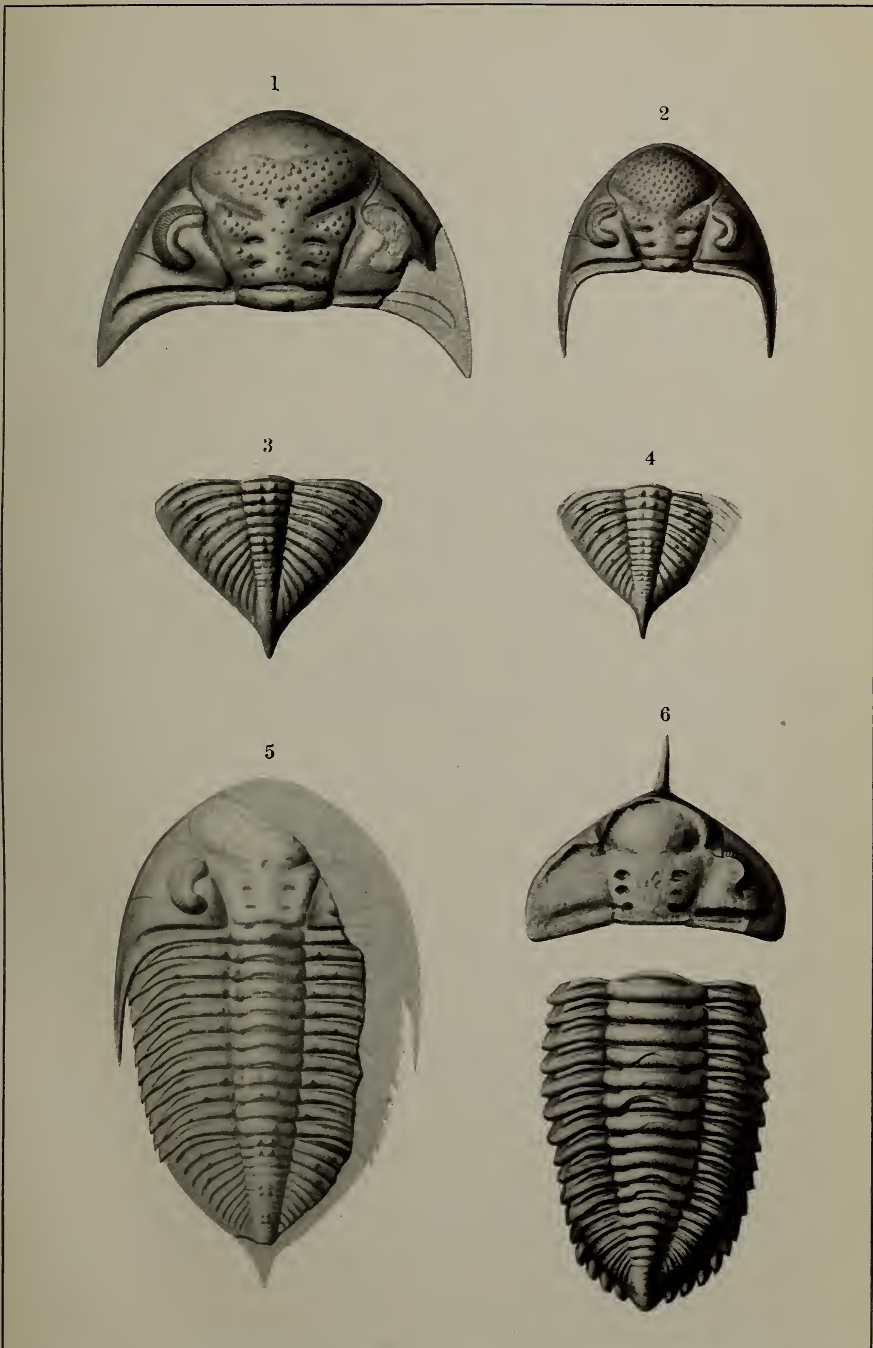
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Plate 6

Cryphaeus sp. nov.?

Fig. 1 A pygidium with very blunt semicircular lappets, indicating a species distinct from the others here noticed.
Locality: Ponta Grossa, São Paulo, Brazil

Cryphaeus australis Clarke

Fig. 2 A pygidium
3 A specimen displaying most of the parts except the pygidial fringe and showing the phacopid hypostoma
4 A nearly entire specimen
5, 6 Larger individuals partly crushed but restored in outline
Locality: Ponta Grossa, São Paulo, Brazil

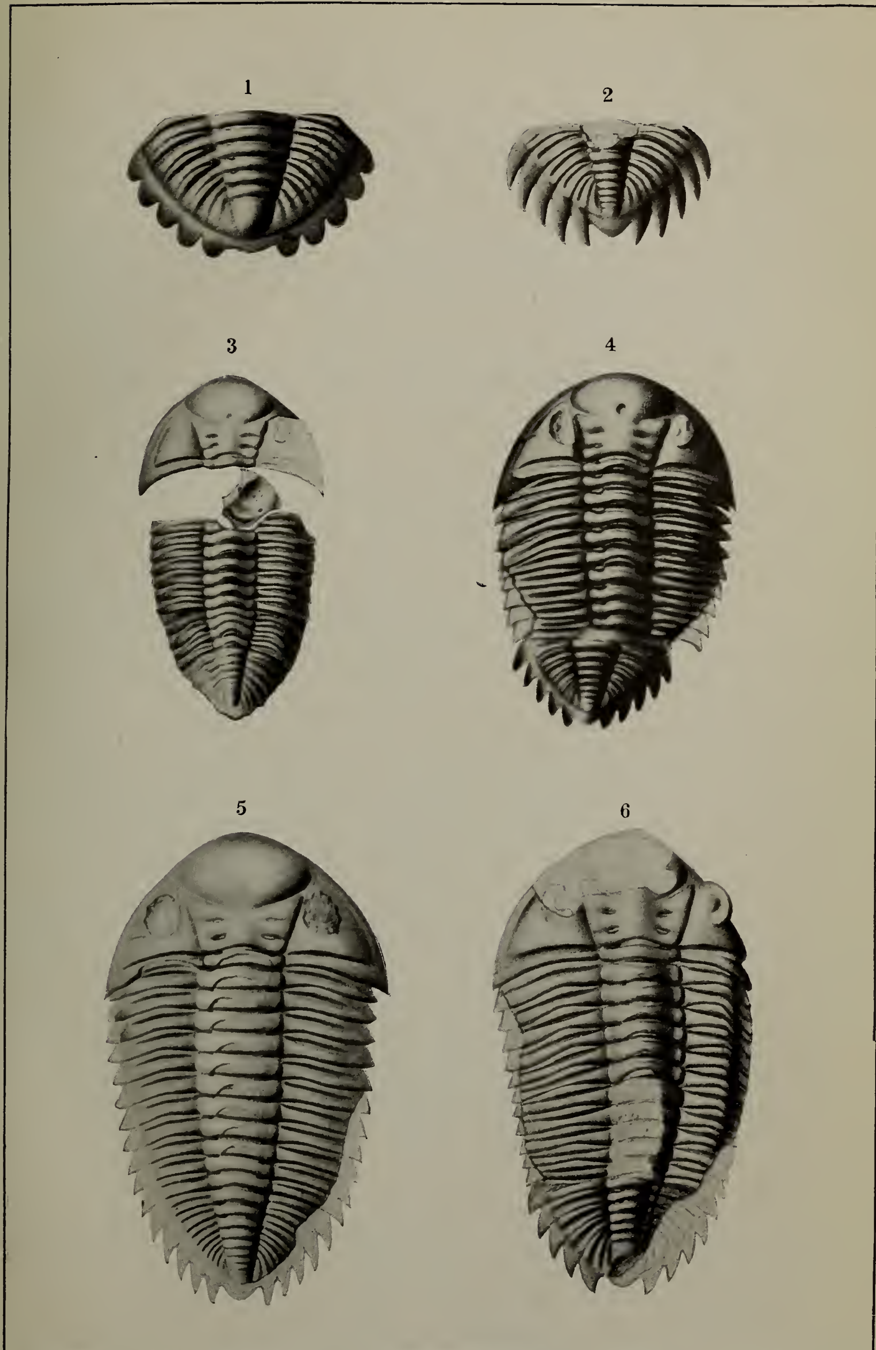
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Plate 7

Dalmanites sp.

Fig. 1, 2 Dorsal and profile views of a cephalon allied to D. acacia and D. ocellus but departing in some structural details. The upturned genal angles are indicated in figure 2

Locality: from a calc-nodule sent to me by Prof. J. B. Woodworth with the note that it was found by Dr Thomas A. Barbour on the old beach of Lake Titacaca at Viacha, Bolivia, elevation 13,500′ A. T.

Calmonia ocellus (Lake)

Fig. 3, 4 Dorsal and profile views of a partly enrolled specimen

5, 6, 7 Three views of a coiled individual showing the characteristic head, small eyes, sharply pointed thoracic segments and a part of the pygidial fringe

Locality: Pebble island, West Falkland

8 An extended specimen incomplete at the pygidium

Locality: Mt Robinson range, Chartres river, West Falkland

Plate 7

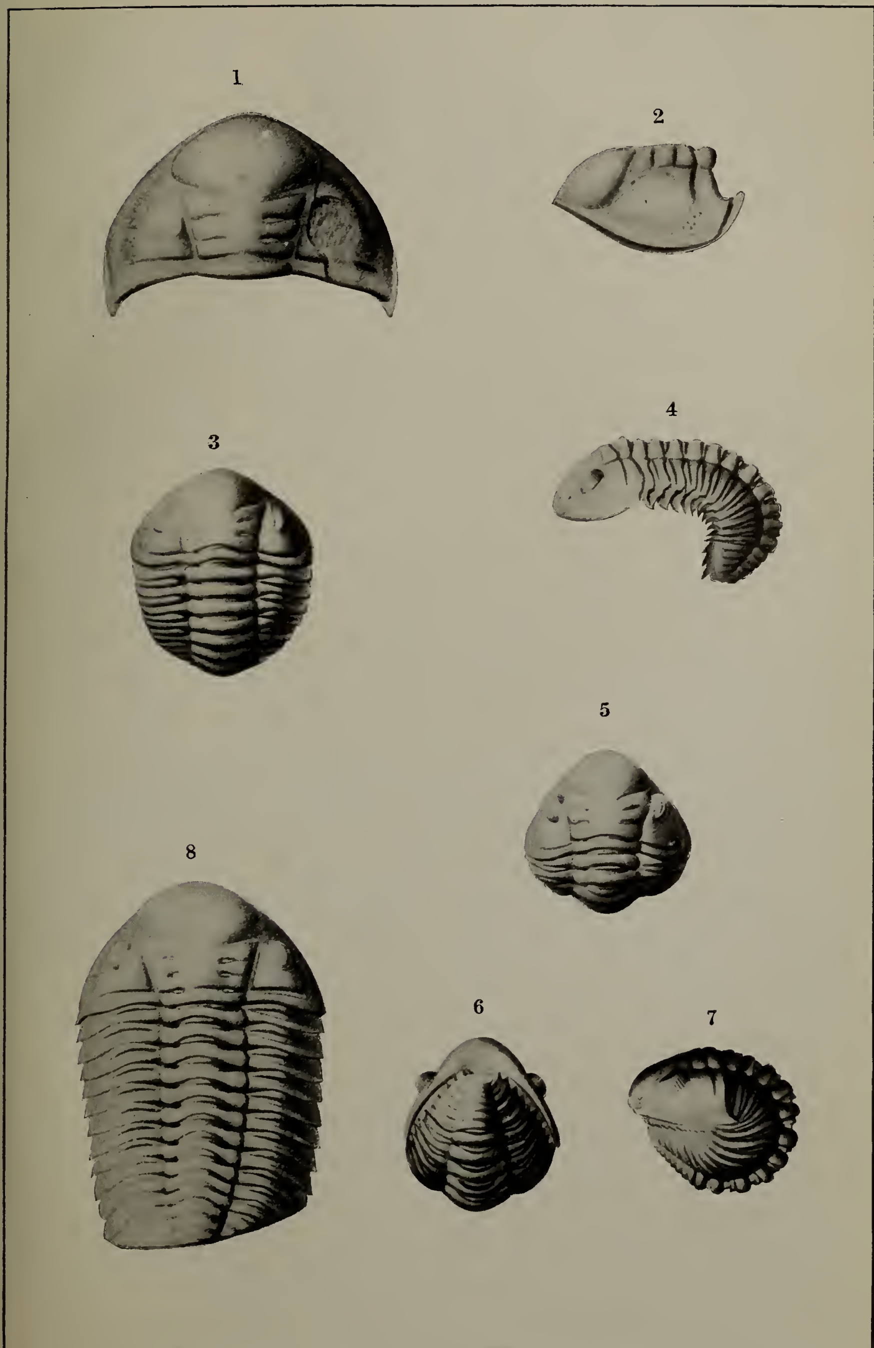

Plate 8

Pennaia pauliana Clarke

Fig. 1, 2 Cephala

3 A pygidium with two thoracic segments attached. x 3

4 The thorax and pygidium, showing the rounded ends of the anterior thoracic segments and 3 lappets of the pygidium

5 A nearly entire individual restored

6 Thorax and pygidium of an incomplete specimen

Locality: Ponta Grossa, São Paulo, Brazil

Calmonia signifer Clarke

(See plate 9)

Fig. 7 Cephalon restored, showing style and position of the eyes and the small cheek spine

8 Anterior structure of the head showing the short apical projection which is often obscured

9 Internal cast of thorax and pygidium

10, 11 Pygidia with terminal spines

Locality: Ponta Grossa, São Paulo, Brazil

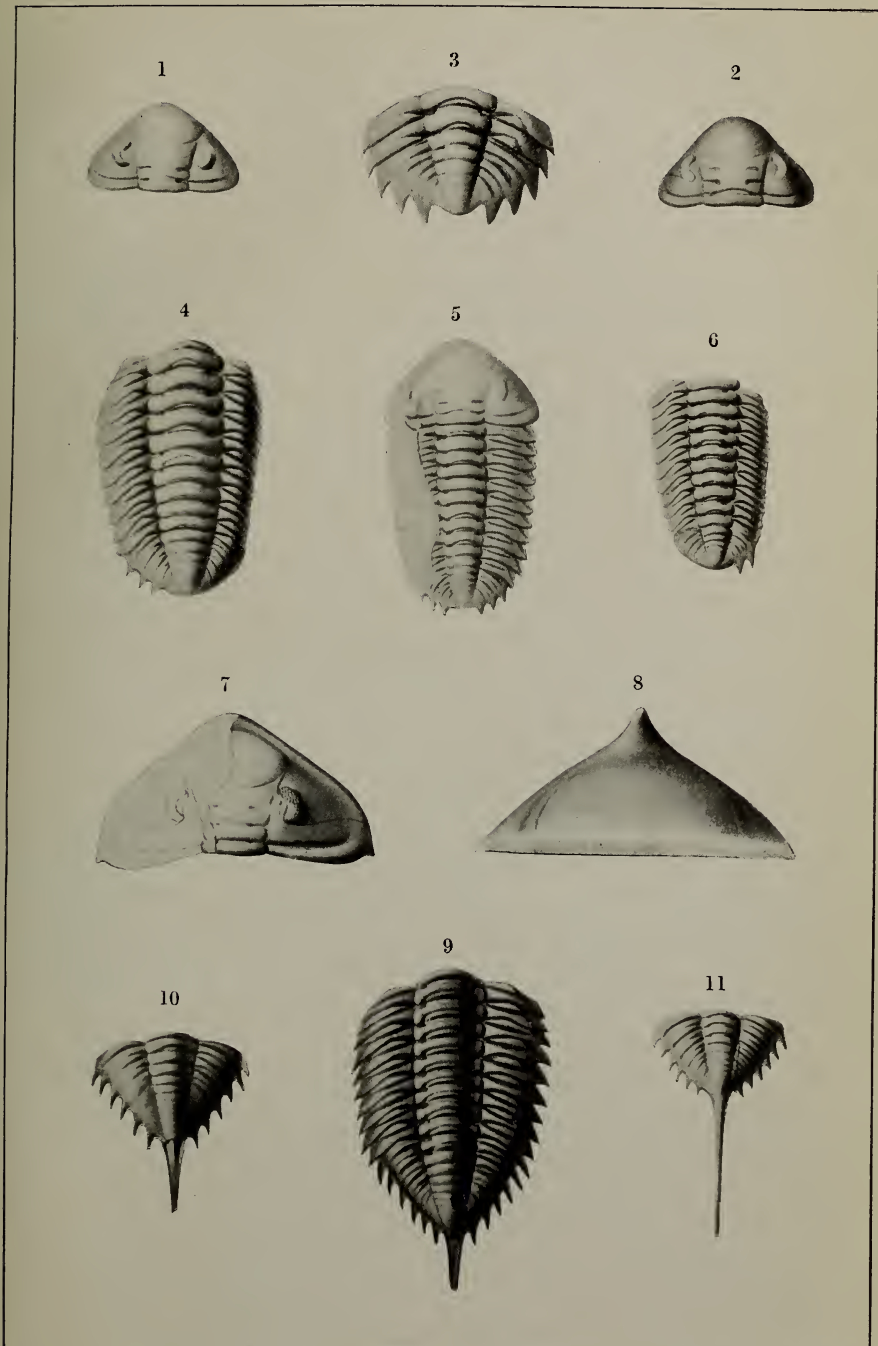
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Plate 9

Calmonia signifer Clarke

(See plate 8)

Fig. 1 A large entire individual in which all the essential characters are well displayed. Attention may be directed to the short head, obscurely lobate glabella, small anterior eyes, angled extremities of the segments becoming sharper backward, the six pairs of pygidiae lappets and the relatively short caudal spine

2 A smaller entire individual with exsert genal spines and a longer caudal spine. The thoracic segments are only ten and one seems to be buried at the junction with the pygidium

3 Head and thorax

4 An entire but somewhat distorted specimen

Calmonia signifer var. **micrischia** Clarke

Fig. 5 A small entire individual

6 A larger entire example

Locality: Ponta Grossa, São Paulo, Brazil

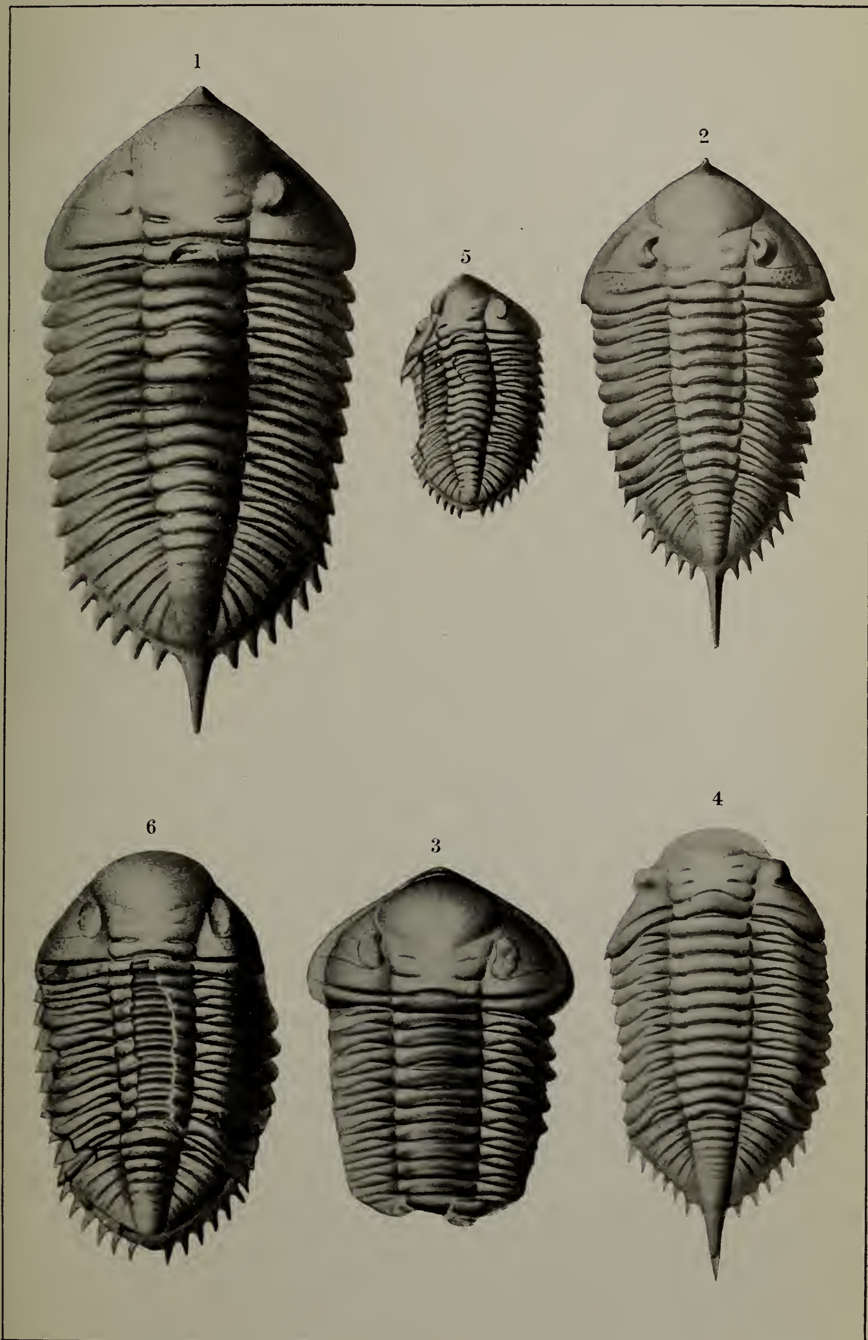
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Plate 10

Calmonia subseciva Clarke

Fig. 1 An extended specimen from which the cephalon has been broken

2 A squeeze taken from the foregoing, showing the cephalic doublure and phacopid hypostoma. x 2

Locality: Ponta Grossa, Brazil

3 An entire specimen, slightly crushed about the head, showing the minute pygidial lappets

4 A nearly entire individual of large size

Locality: Jaguariahyva, São Paulo, Brazil

Proboloides cuspidatus Clarke

Fig. 5 A small cephalon

6 A laterally crushed specimen displaying a part of the proboscis, the sutural and genal spines and the acute spinules of the first thoracic segments

7 A cheek with sutural and genal spines. x $1\frac{1}{2}$

8 A cephalon with its long proboscis, showing also the genal spine and base of the sutural spine

9 Large cephalon with proboscis broken

Locality: Ponta Grossa, Brazil

Proboloides pessulus Clarke

Fig. 10 A specimen with all parts conjoined; showing the aspect of the head, its proboscis and sutural spines, the sharply terminated thoracic segments and apparently smooth margined pygidium

Locality: Jaguariahyva, São Paulo, Brazil

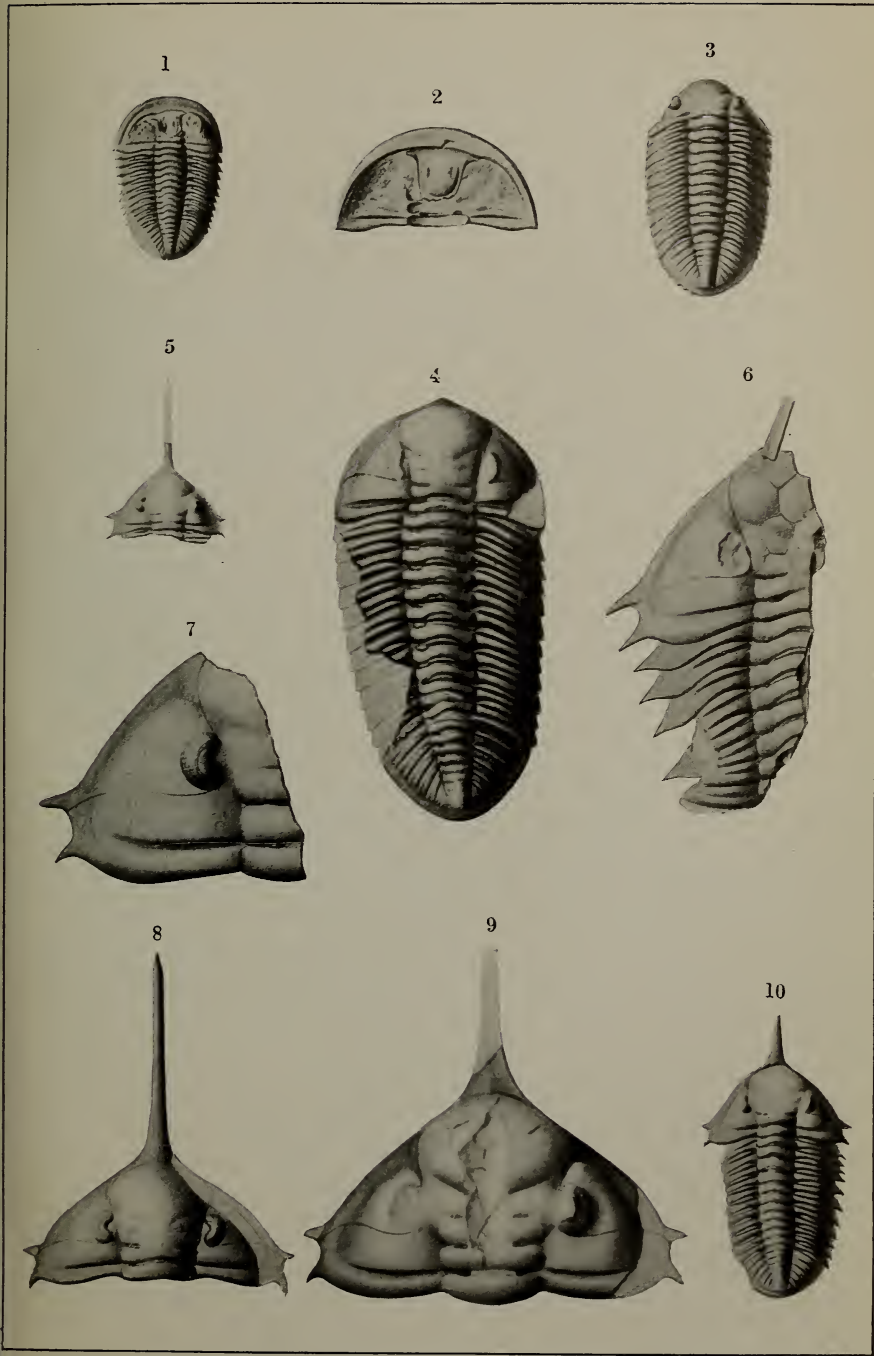
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Plate 11

Conularia ulrichana Clarke

Fig. 1 Enlarged fragment showing nature of ornament
2 A small example. x 2
3 A characteristic example
Locality: Tybagy, São Paulo, Brazil

Conularia africana Salter

Fig. 4 An undistorted fragment
5 A well-developed, nearly entire specimen
Locality: Ponta Grossa, Brazil

Hyolithus subaequalis (Salter)

Fig. 6, 7 The two sides, with operculum in place
Locality: Tybagy, São Paulo, Brazil

Orthoceras sp. (cf. gamkaensis Reed)

Fig. 8 Part of a shell retaining fine concentric surface ornament
Locality: Ponta Grossa, Brazil

Kionoceras zoilus Clarke

Fig. 9 The only example observed
Locality: Ponta Grossa, Brazil

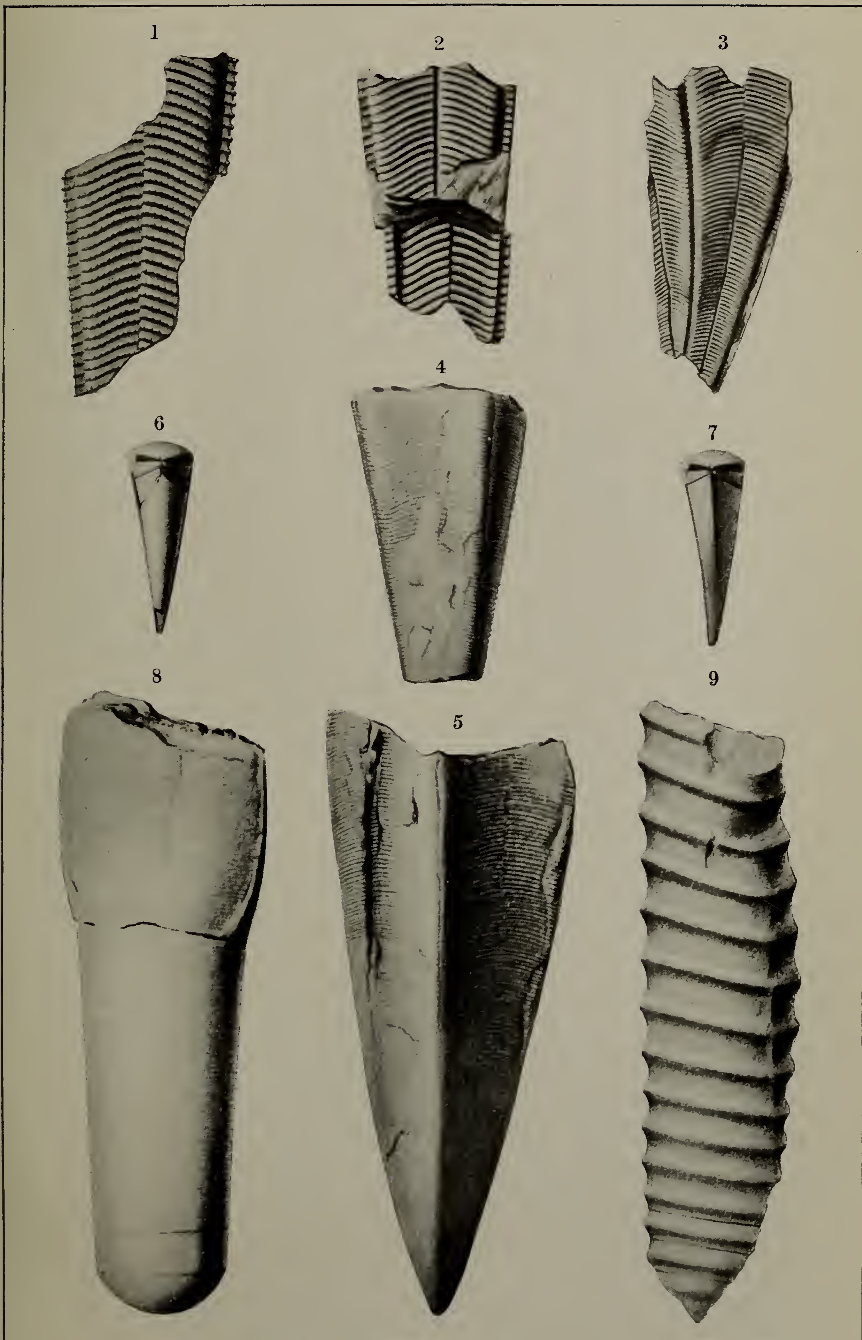
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Plate 12

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Tentaculites jaculus Clarke

Fig. 1 A cluster of tubes with characteristic irregularity of annulation. Natural size
Locality: Ponta Grossa, Brazil

Tentaculites crotalinus Salter

Fig. 2 A cluster of tubes. x 3
Locality: Ponta Grossa, Brazil

Tropidocyclus antarcticus Clarke

Fig. 3 Two accidently conjoined individuals
4 Dorsal view showing the character of the striae. x 1½
Locality: Pebble island, West Falkland

Plectonotus (Bucaniella) hapsideus Clarke

Fig. 5 A laterally compressed individual showing the dorsal seam
6, 7 Two other similarly compressed shells
Locality: Ponta Grossa, Brazil

Bellerophon quadrilobatus Salter?

Fig. 8 An internal cast of a trilobed shell which may pertain to this species
Locality: Pebble island, West Falkland

Diaphorostoma allardycei Clarke

Fig. 9, 10, 11 Three views of this species, indicating its form and style of ornament
Locality: Pebble island, West Falkland

Plectonotus (Bucaniella) dereimsi Knod

Fig. 12, 13, 14 Views of more or less complete examples of these shells
Locality: Ponta Grossa, Brazil

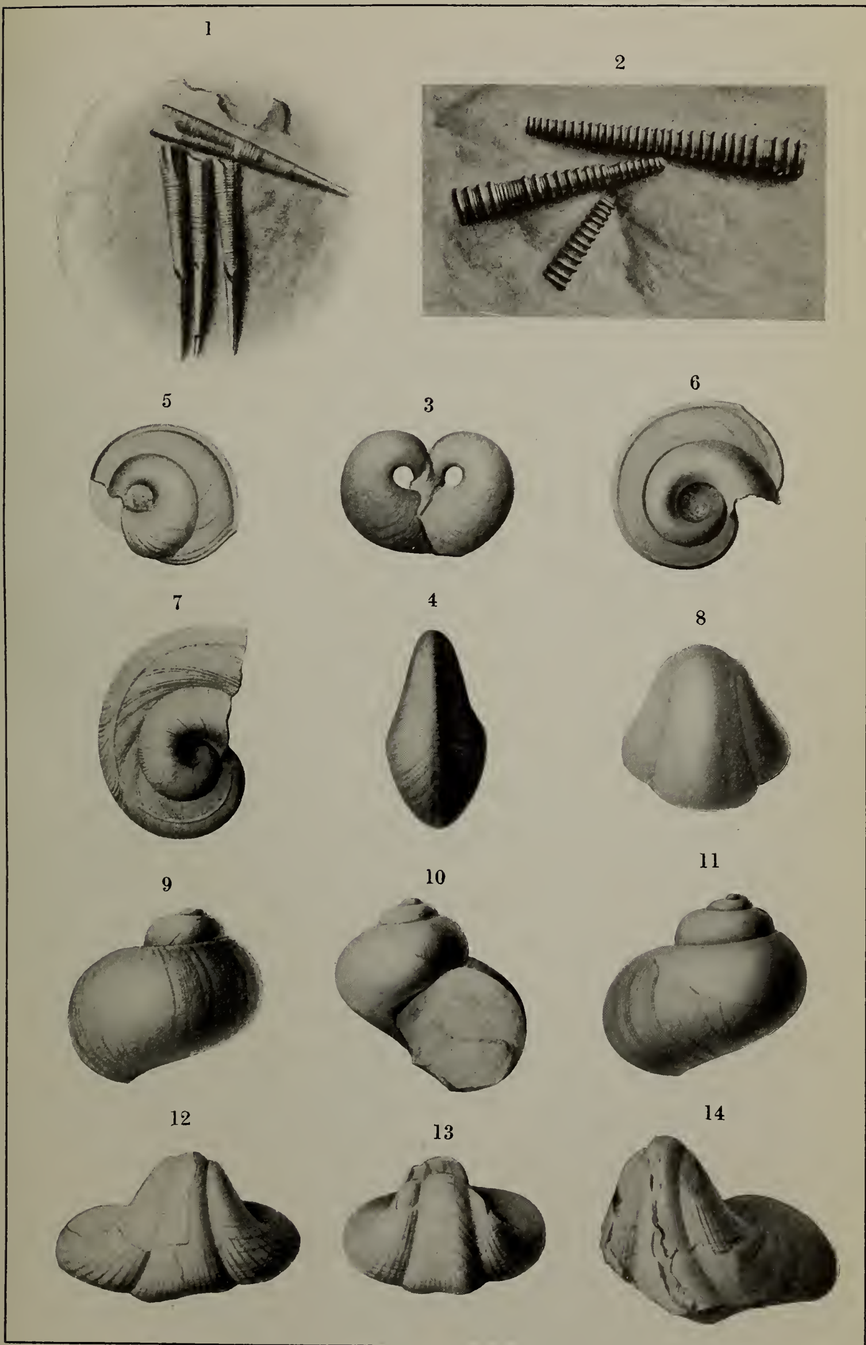
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Plate 13

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Ptomatis moreirai Clarke

Fig. 1, 2 Exteriors of two examples
Locality: Ponta Grossa, Brazil

Nuculites reedi Clarke

Fig. 3, 4, 5 Sculpture casts showing the sinuous posterior slopes
Locality: Ponta Grossa, Brazil

Nuculites parai Clarke

Fig. 6, 7 Sculpture casts from the Upper Devonic black shale, near Ereré, State of Pará, Brazil

Nuculites sharpei Reed

Fig. 8 Sculpture casts of both valves
9, 10 Other examples of the species
Locality: Ponta Grossa, Brazil
11, 12 A large specimen of this type with rather heavy clavicles but with the sinuous posterior slopes
Locality: Pebble island, West Falkland

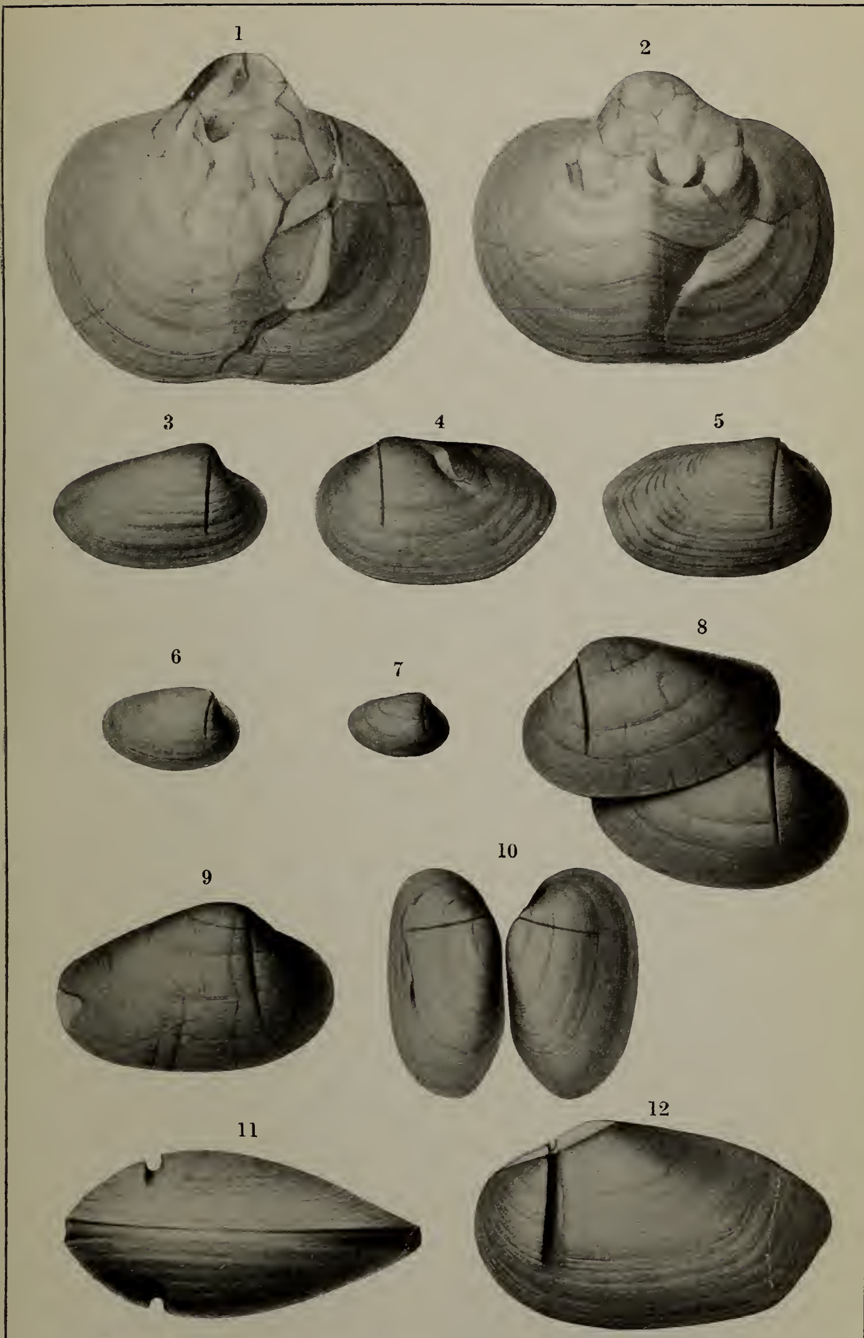
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Plate 14

Nuculana inornata (Sharpe)

Fig. 1, 2 Opposite sides of the same specimen
3 Another characteristic example
Locality: Ponta Grossa, Brazil

Palaeoneilo rhysa Clarke

Fig. 4, 5 Left and right valves
6 Enlargement of surface ornament of figure 4
Locality: Ponta Grossa, Brazil

Nuculites pacatus Reed

Fig. 7 Interior cast of conjoined valves with strong clavicular ridges
Locality: Jaguariahyva, São Paulo, Brazil
8 Sculpture cast of right valve
Locality: Ponta Grossa, Brazil

Palaeoneilo magnifica Clarke

(See plate 15)

Fig. 9 Internal cast of right valve, showing part of hinge. The borings are those of the sponge Clionolithus priscus (McCoy)
Locality: Ponta Grossa, Brazil

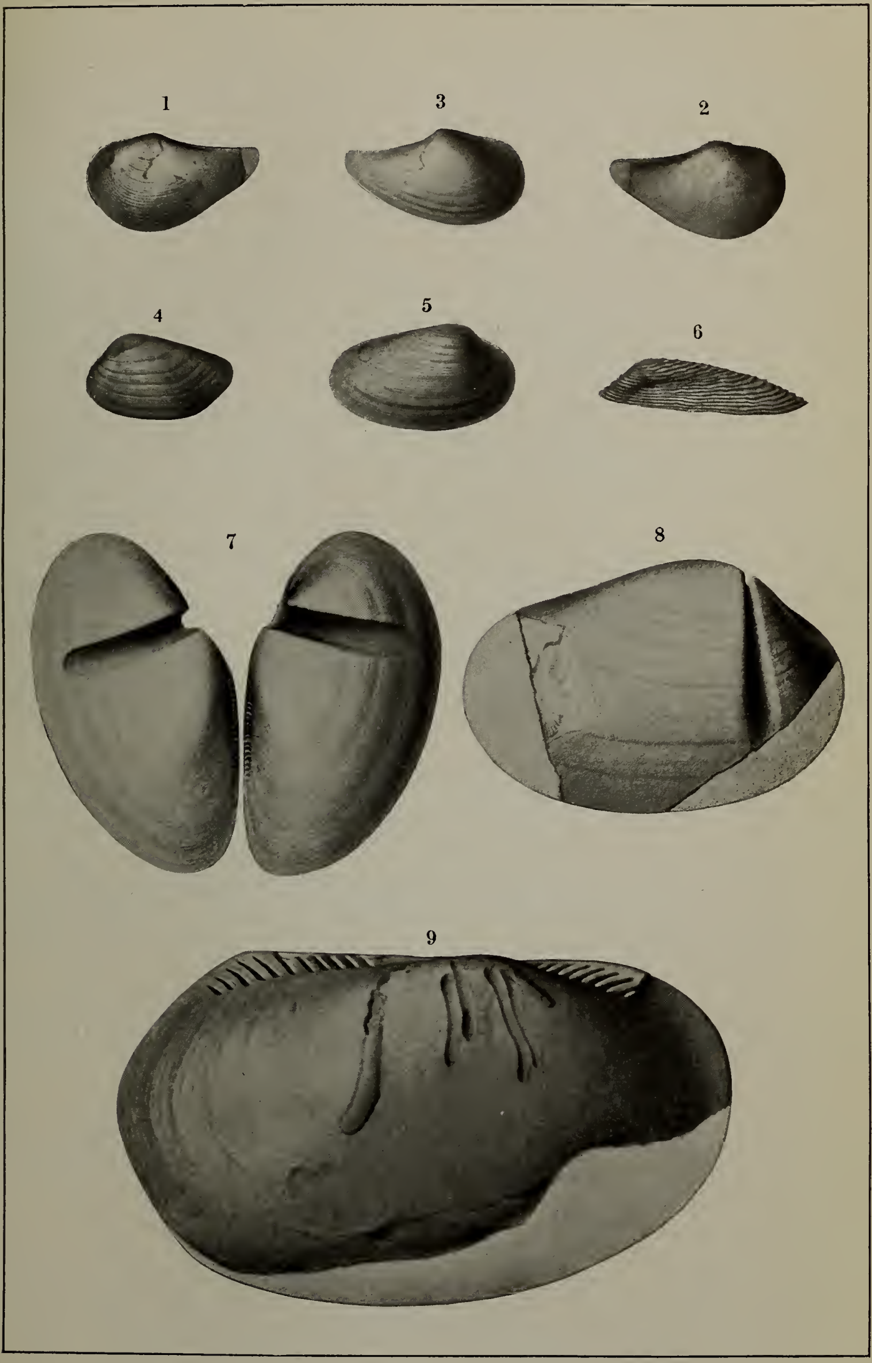
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Plate 15

Palaeoneilo magnifica Clarke

(See plate 14)

Fig. 1 Exterior of left valve
2 Sculpture cast of conjoined valves
Locality: Ponta Grossa, Brazil

Palaeoneilo sculptilis Clarke

Fig. 3 A weathered right valve showing the radial ornament. From the Upper Devonic shale of Ereré, Pará, associated with Schizobolus truncatus and Nuculites parai

Palaeoneilo sancticrucis Clarke

Fig. 4, 5 Right valves of this species
Locality: Ponta Grossa, Brazil

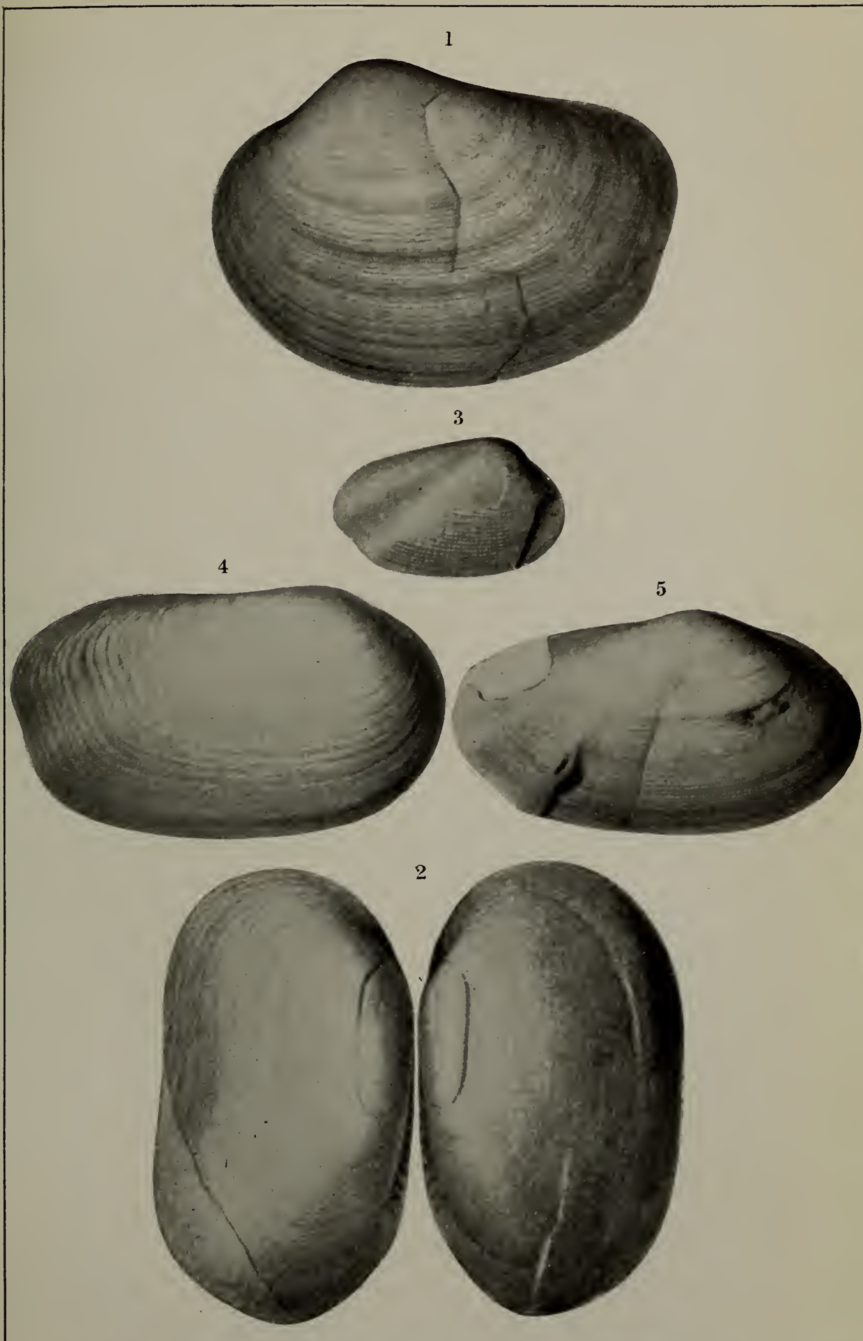
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Plate 16

Prothyris (Paraprothyris) knodi Clarke

Fig. 1, 2 Conjoined valves, showing the anterior byssal notch and posterior cardinal ridge

3, 4, 5, 6 Other valves showing in more detail the cardinal characters

7 Enlargement of posterior part of specimen figure 4

Locality: Ponta Grossa, Brazil

Cardiomorpha ? colossea Clarke

Fig. 8 Sculpture cast of a right valve of medium size

Locality: Ponta Grossa, Brazil

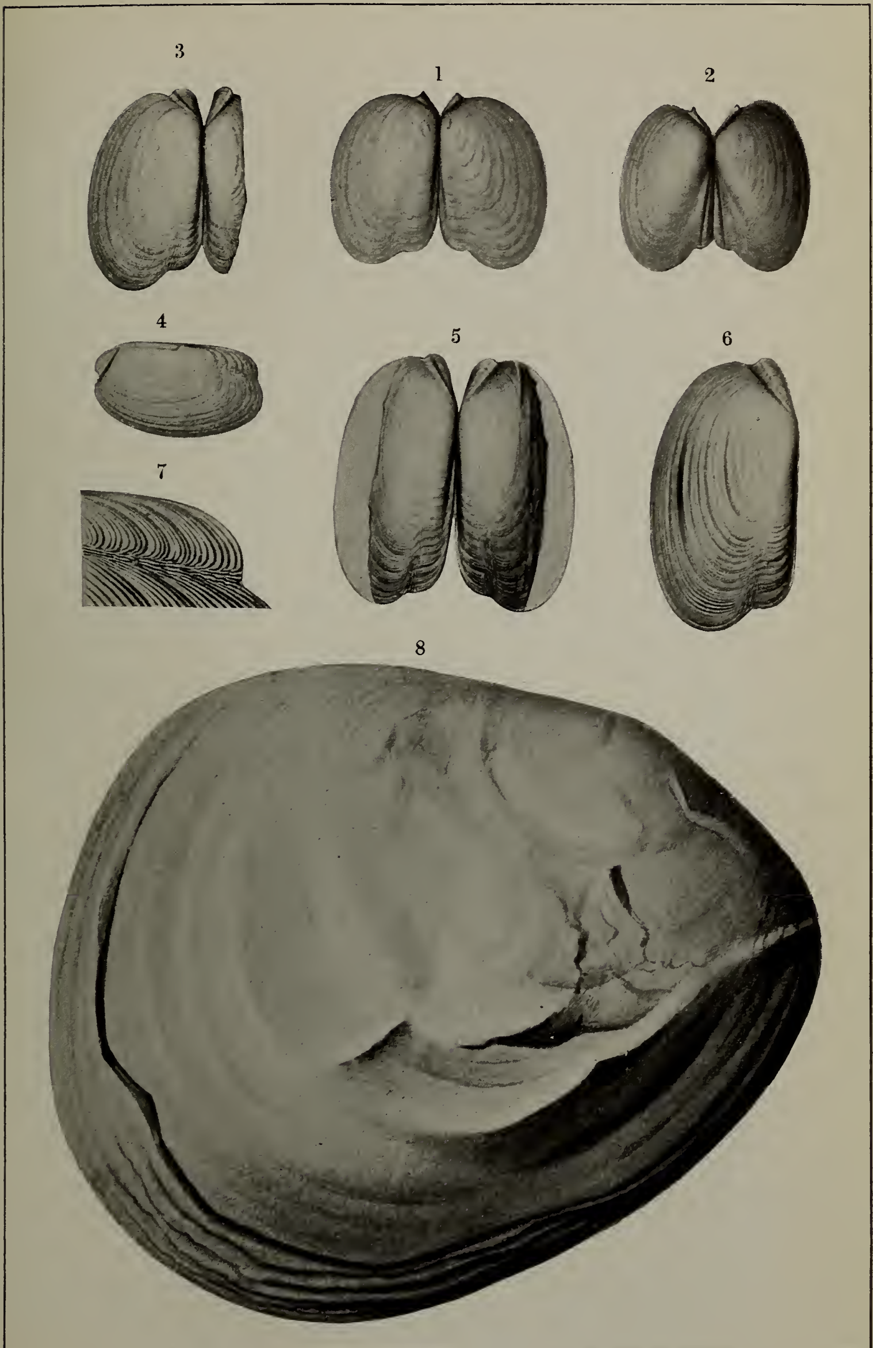
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Plate 17

Pleurodapis multicincta Clarke

Fig. 1, 2 Right and left valves

3 Sculpture casts of conjoined valves with suppression of some of the posterior ridges. The abscission of the umbones by pressure on the hinge-plates is noticeable here, as on the succeeding figures

4 The hinge, showing anterior muscle scars and a broadened platform behind. x 2

5, 6 Right valves, showing considerable divergence in the development of the ridges

Locality: Ponta Grossa, Brazil

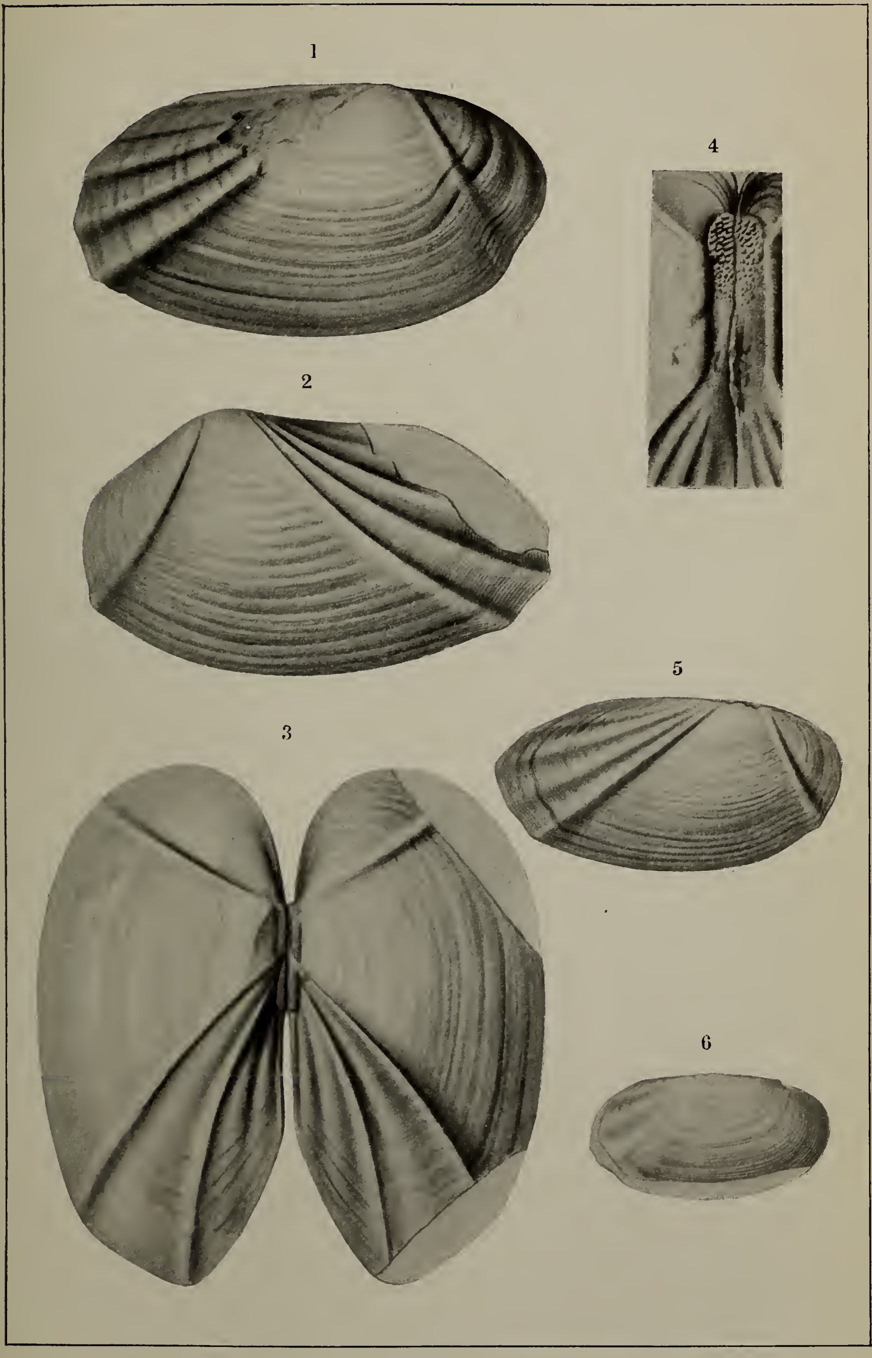
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Plate 18

Janeia bokkeveldensis Reed

Fig. 1 Conjoined valves showing the overlapping left
2 The two valves with overlapping right
3 A large left valve
4 Sculpture of posterior part of valve. x 3
Locality: Ponta Grossa, Brazil

Janeia braziliensis Clarke

Fig. 5 Right side of conjoined valves, showing the overlapping left
6 A small specimen
7 Large shell with valves slightly spread
8 Left view of conjoined valves
Locality: Tybagy, São Paulo, Brazil

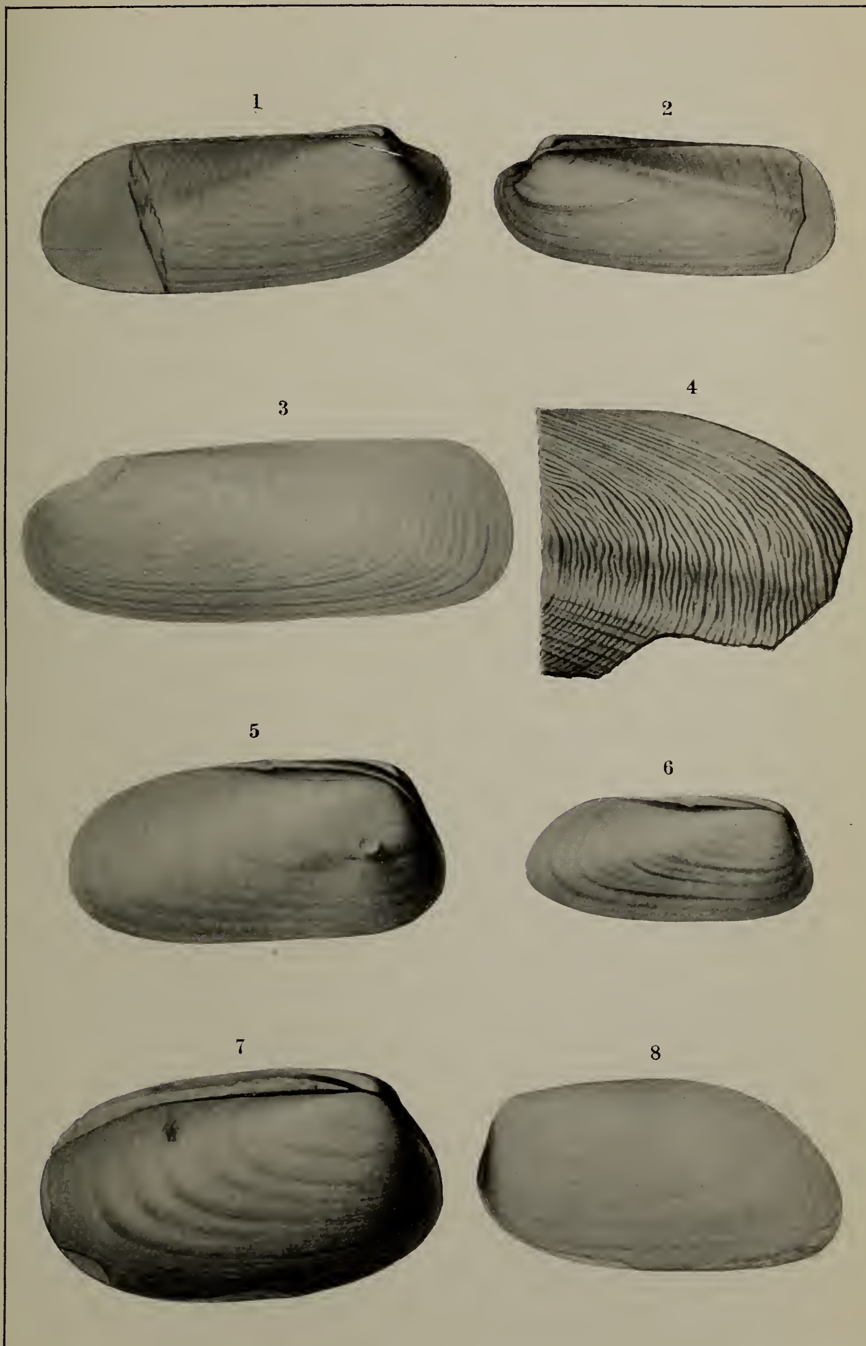
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Plate 19

Goniophora abbreviata Clarke

Fig. 1, 2 Sculpture casts of right valves
Locality: Jaguariahyva, São Paulo, Brazil

Palaeanatina erebus Clarke

Fig. 3, 4, 5 Conjoined expanded valves
Locality: Ponta Grossa, Brazil

Cypricardella? olivieria Clarke

Fig. 6 Conjoined valves, natural size
7 The left valve, x 3
Locality: Ponta Grossa, Brazil

Sphenotus lagoensis Clarke

Fig. 8 Expanded conjoined valves with the crescence ridge somewhat intensified by compression
9 A right valve
Locality: Lago, state of São Paulo, Brazil

Leptodomus capricornus Clarke

Fig. 10 A right valve
11 A left valve
12 Enlargement of posterior slope
Locality: Ponta Grossa, Brazil

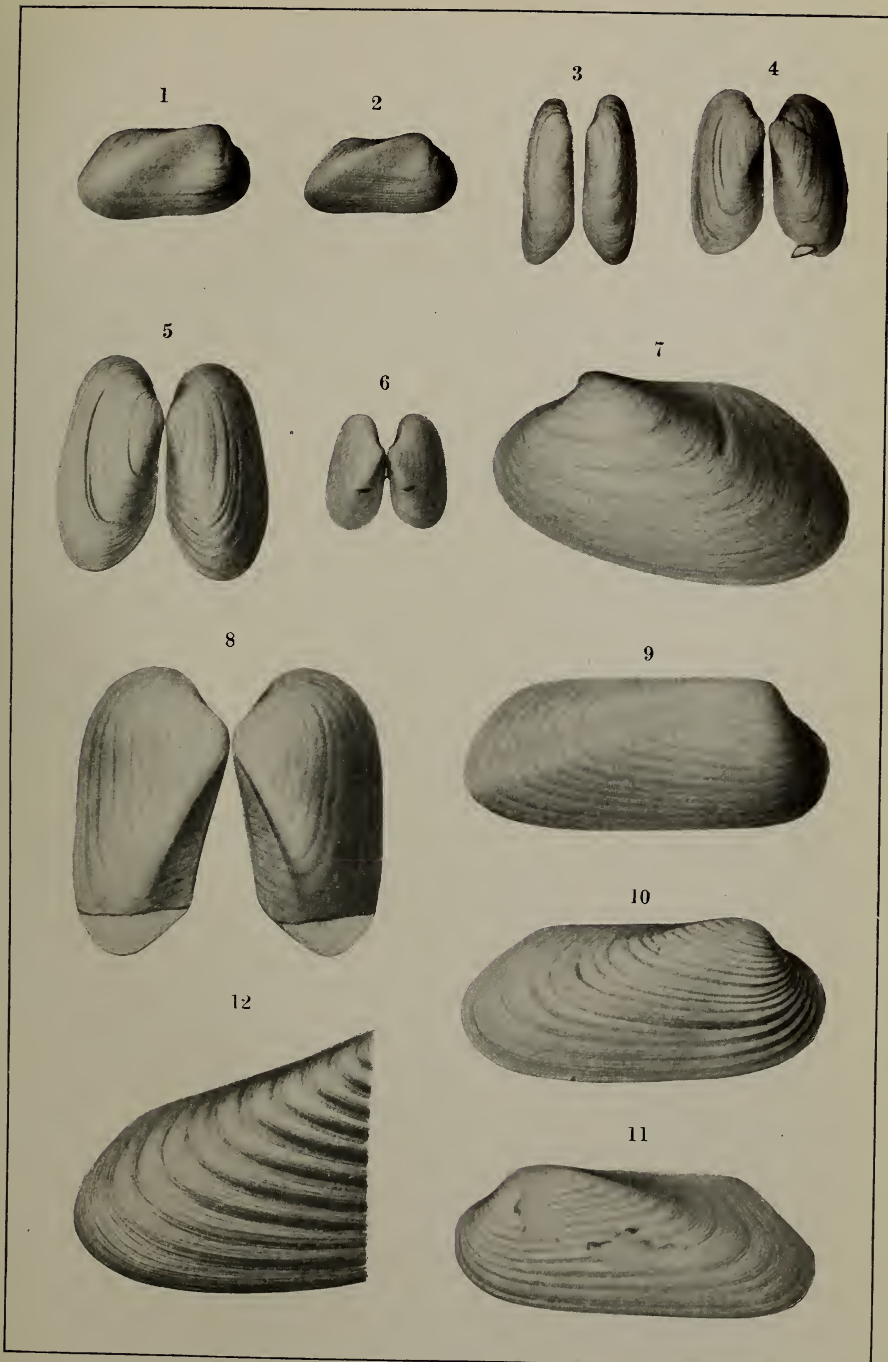
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Plate 20

Modiomorpha austronotica Clarke

Fig. 1, 2 Sculpture casts of right and left valves
3 A right valve
4 Expanded valves in juxtaposition
Locality: Ponta Grossa, Brazil

Modiomorpha ? scaphula Clarke

Fig. 5, 6 Right and left sculpture valves
Localities: Ponta Grossa and Tybagy, Brazil

Phthonia ? epops Clarke

Fig. 7 Right valve showing surface characters
8 Enlargement of surface on posterior slope
Locality: Jaguariahyva, Brazil

Pholadella cf radiata Hall

Fig. 9 Fragment of a large specimen provisionally referred to this species
Locality: Tybagy, Brazil

Leptodomus ulrichi Clarke

Fig. 10, 11 Left valves of this species
Locality: Ponta Grossa, Brazil

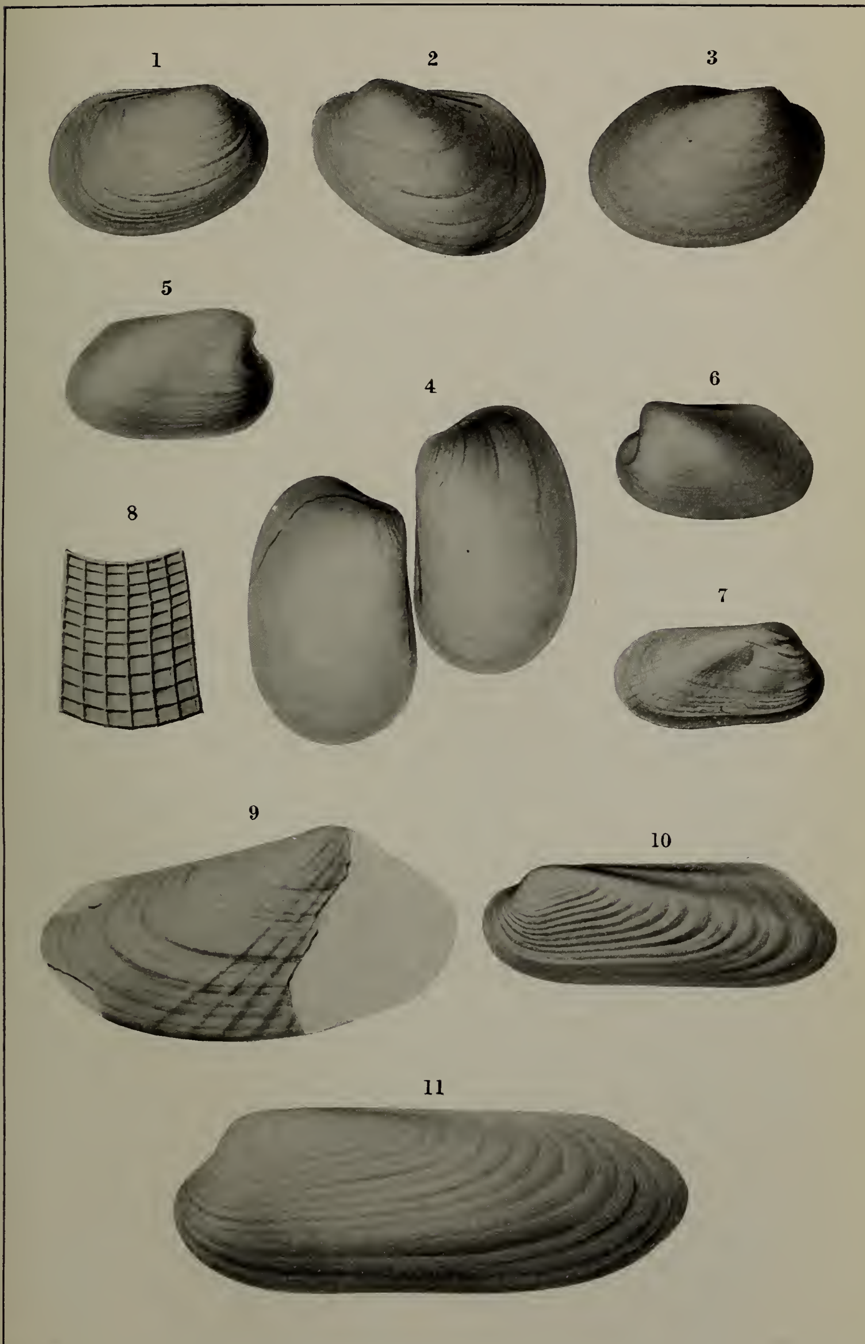
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Plate 21

Derbyina smithi (Derby)

Fig. 1, 2 Copies of Derby's figures of the brachial apparatus
3 Ventral side of an internal cast. x 2
4, 5, 6 Ventral profile and dorsal views of an internal cast. x 2
Locality: Ponta Grossa, Brazil

Paranaia margarida (Derby)

Fig. 7, 8 Derby's figures of the brachial apparatus
Locality: Sant'Ana de Chapada, Mato Grosso, Brazil

Cryptonella ? baini (Sharpe)

Fig. 9 Cast of ventral valve
10, 11 Dorsal views of internal casts
12 Dorsal valve with hinge plate
13 Enlargement of the surface of an inside cast, showing the filling of the shell punctures
Locality: Tybagy, São Paulo, Brazil

Rensselaeria falklandica Clarke

Fig. 14 Internal cast of ventral valve
15 Dorsal view of an internal cast
Locality: Port Howard, East Falkland

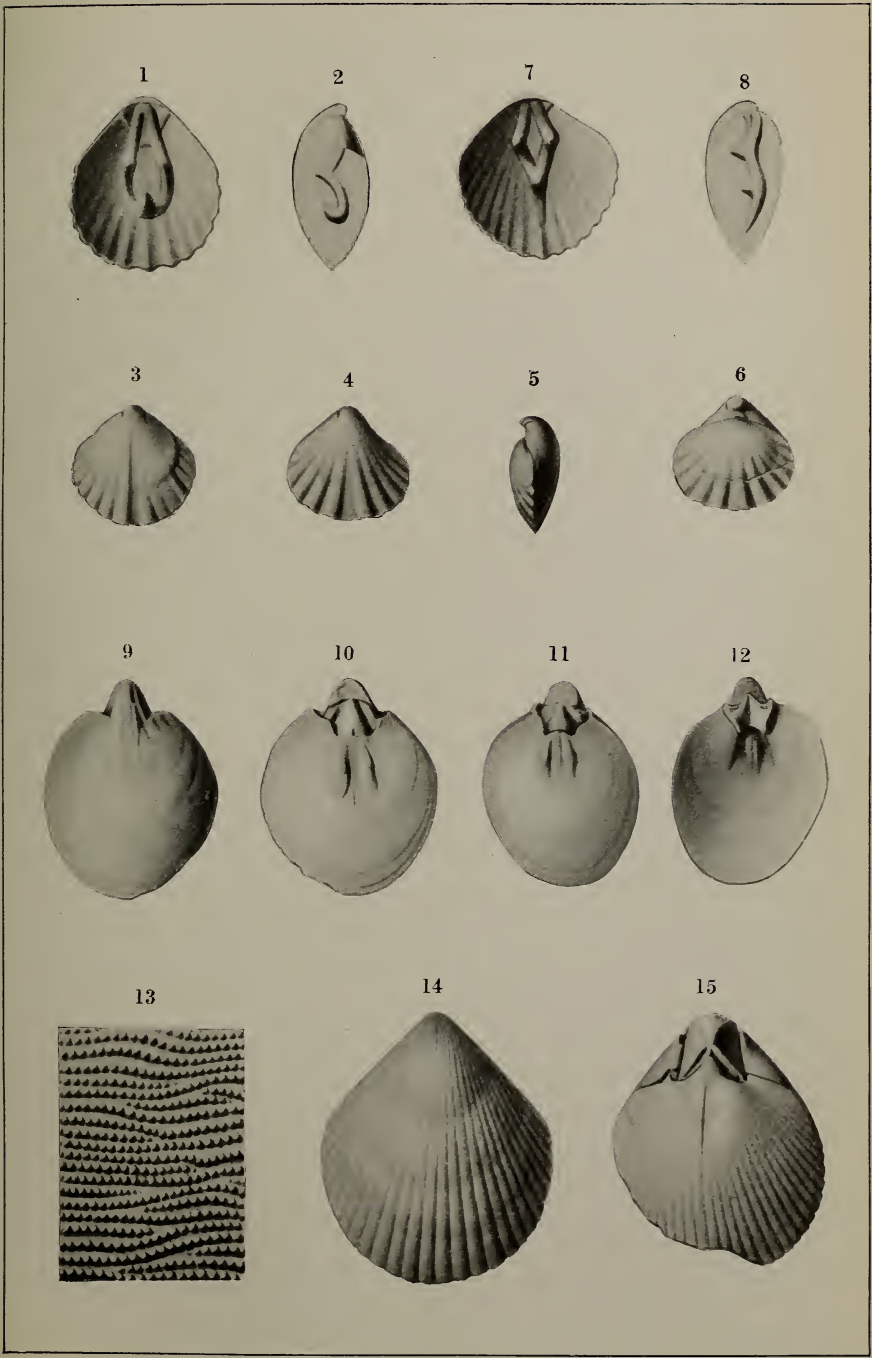
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Plate 22

Spirifer antarcticus Morris and Sharpe

Fig. 1 Ventral cardinal view of a shell without deltidium, but with apical callus

2 Similar view of an old shell with deltidium

Locality: Port Louis, East Falkland

3 Enlargement of surface

Locality: Jaguariahyva, Brazil

4 Enlargement of surface

6, 7 Dorsal valves

8 Exterior of a large individual

9 Internal cast of the same valve

Locality: Port Louis, East Falkland

Spirifer hawkinsi Morris and Sharpe

Fig. 10 Dorsal valve

11 Dorsal side of an internal cast

Locality: Port Louis, East Falkland

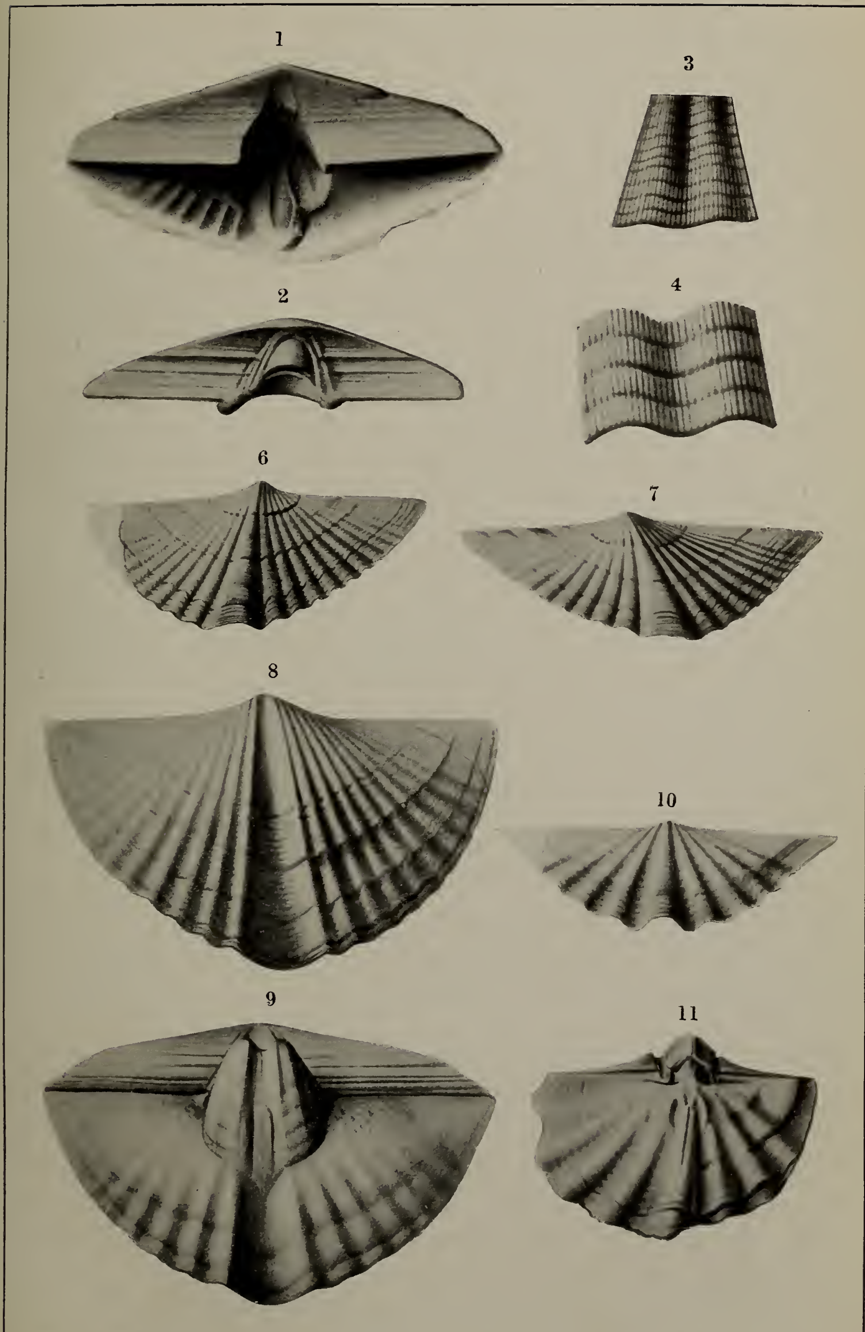
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Plate 23

Spirifer kayserianus Clarke

Fig. 1 A well-preserved dorsal valve, with the characteristic mature sculpture

2 Sculpture cast of the ventral valve

3, 4 Dorsal valves of adult shells

Locality: Ponta Grossa, Brazil

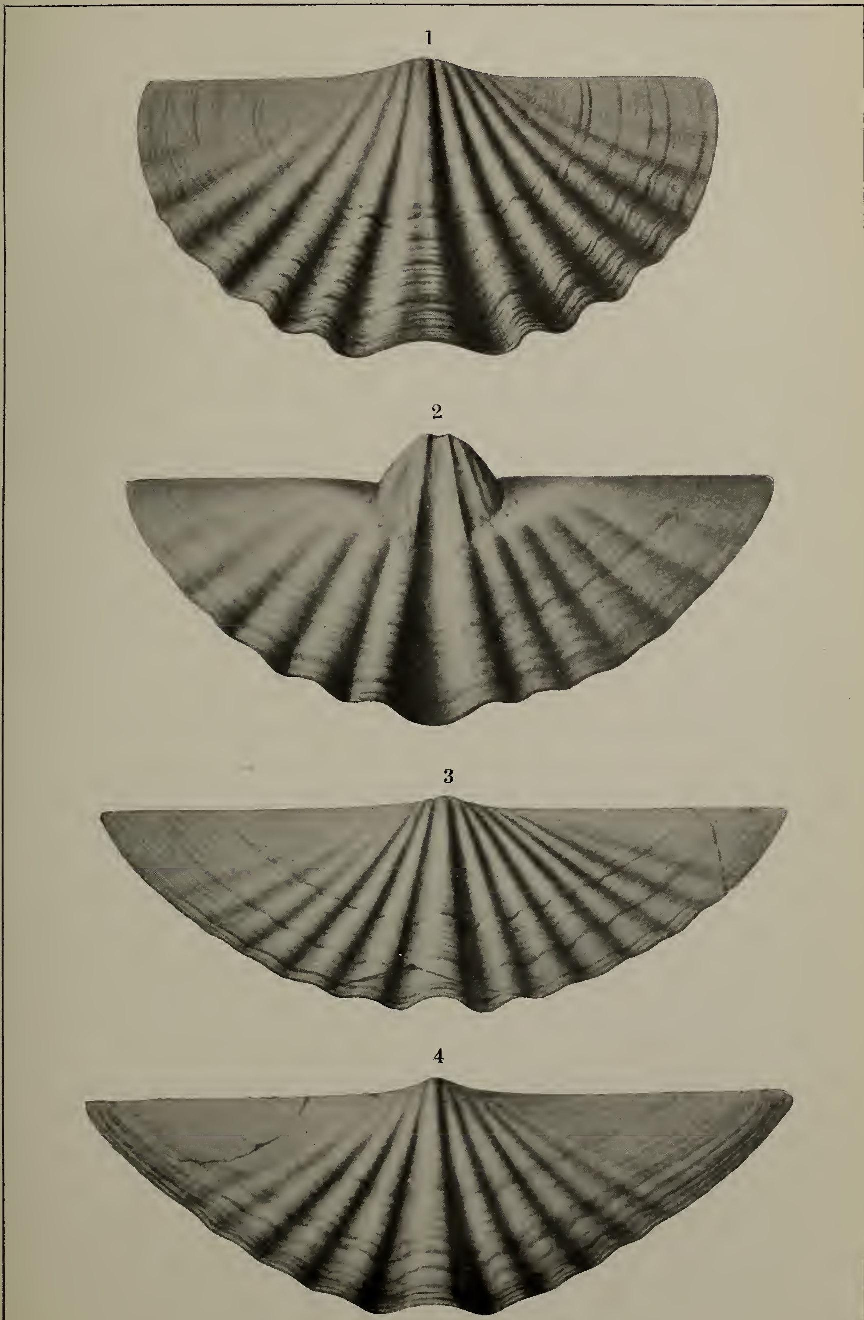

Plate 24

Spirifer iheringi Kayser

(See plate 25)

Fig. 1, 2 Dorsal aspects of internal casts of young shells
3 Front view of conjoined valves of a mature individual
4 Enlargement of surface in a mature valve
5 A mature dorsal valve
6 Dorsal view of a characteristic internal cast
7, 8 The cardinal process in different stages of development
Locality: Tybagy, state of São Paulo, Brazil

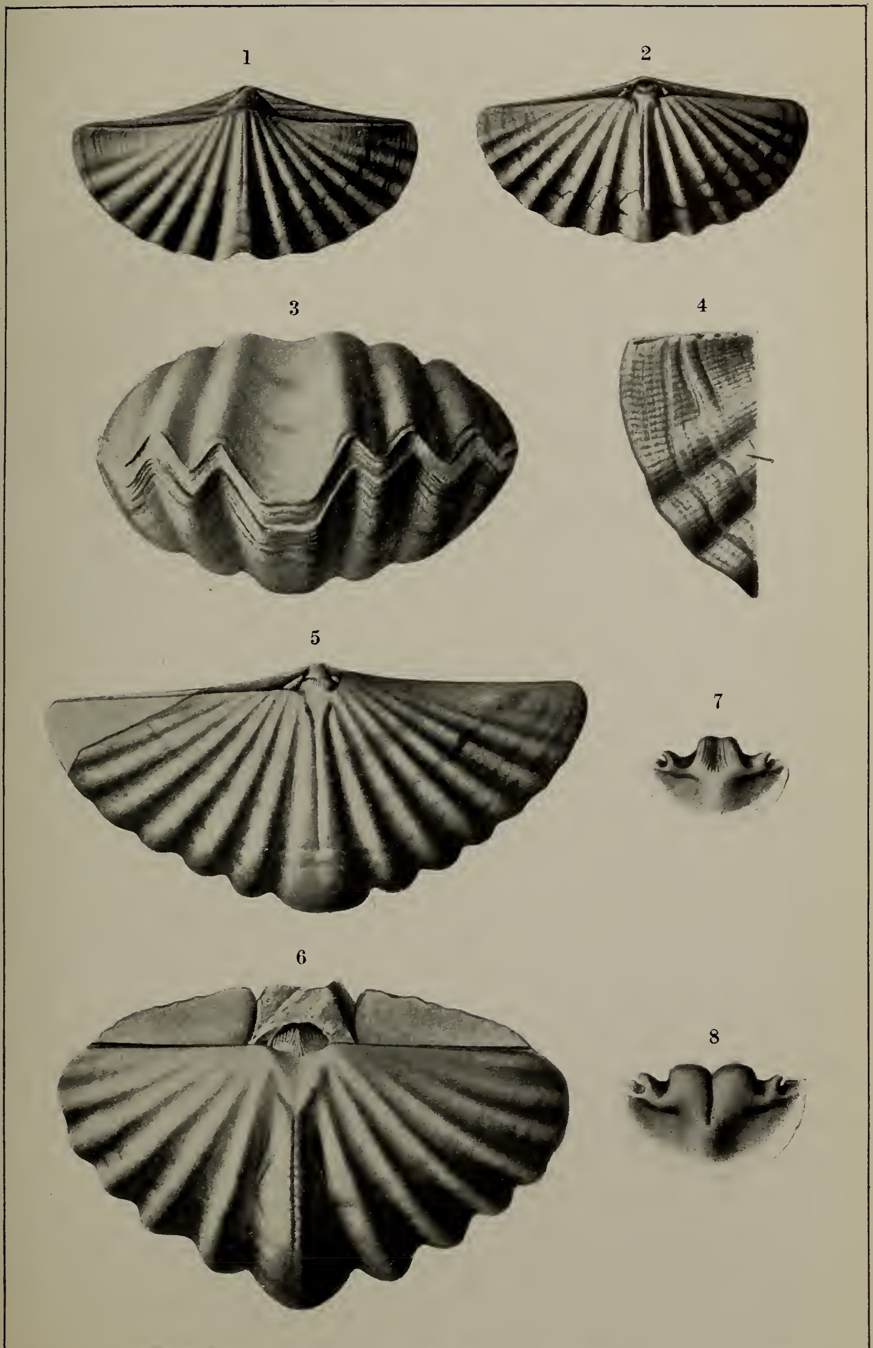
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Plate 25

Spirifer lauro-sodreanus Katzer

Fig. 1, 2 Two views of the type specimen
Locality: Maecurú sandstone, Rio Maecurú, Pará

Spirifer iheringi Kayser

(See plate 24)

Fig. 3 Ventral view of large internal cast
4 View of large ventral cast
Locality: Tybagy, Brazil

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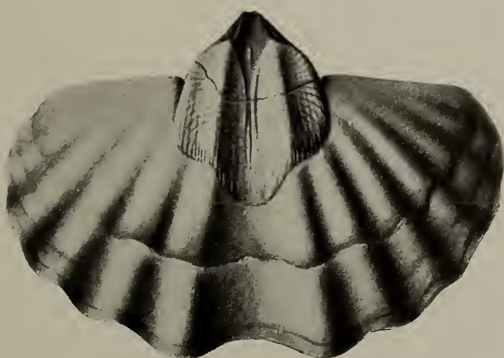

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Plate 26

Spirifer katzeri Clarke

Fig 1, 2 View of a dorsal valve, showing the elevation of the fold and the number of ribs

Locality: Maecurú sandstone, Rio Maecurú, Pará

Spirifer contrarius Clarke

Fig. 3, 4 Casts of dorsal valves showing sharp, distinct ribs and broadly concave interspaces

Locality: Ponta Grossa, Brazil

Spirifer parana Clarke

Fig. 5 A dorsal valve with few broadly rounded ribs

6 A crushed specimen with similar characters

Locality: Ponta Grossa, Brazil

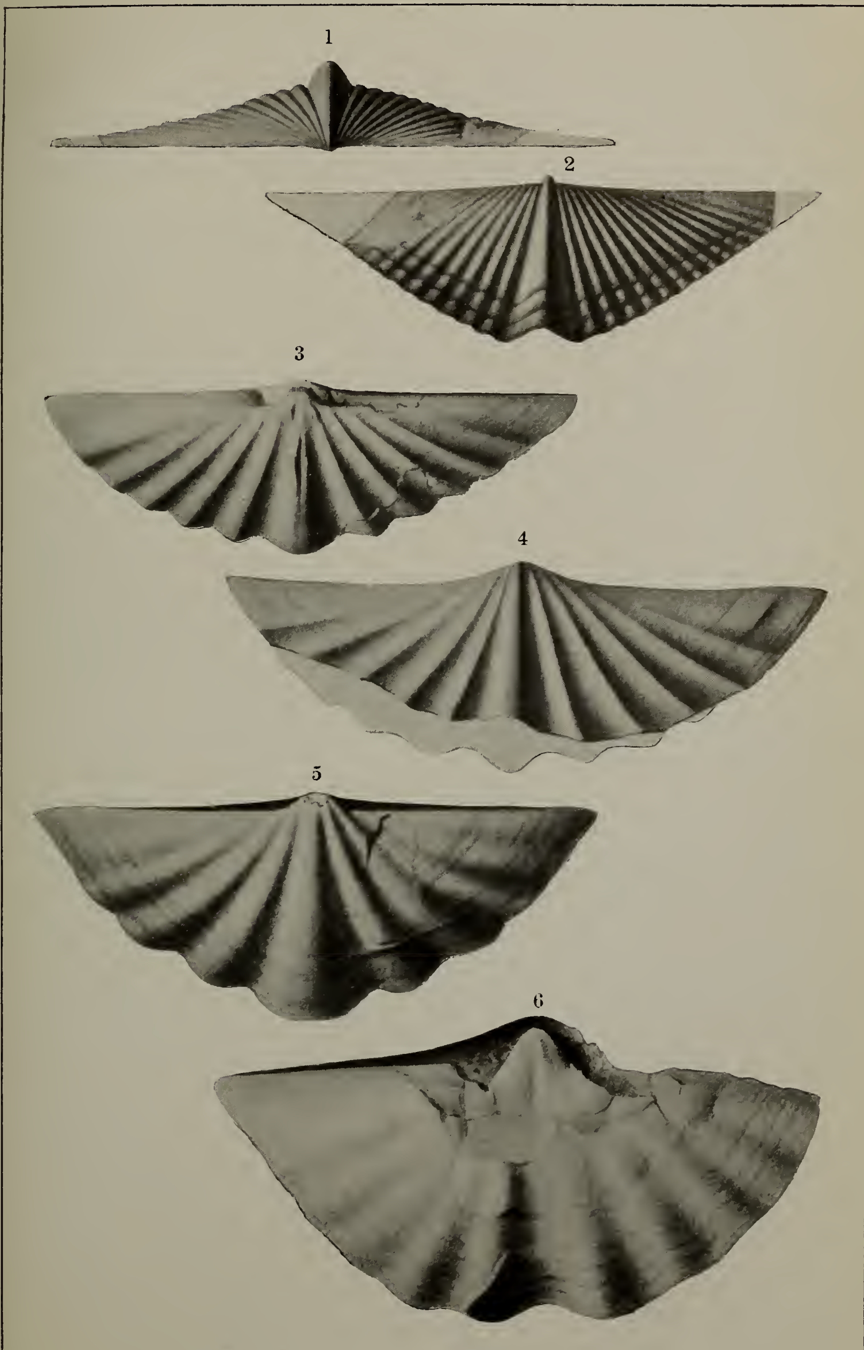
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Plate 27

Derbyina whitiorum Clarke

Fig. 1, 2 Exterior and internal cast of ventral and dorsal valves
3 Enlargement of ventral hinge
4 A dorsal valve
Locality: Ponta Grossa, Brazil

Leptocoelia flabellites (Conrad)

Fig. 5 Exterior of an average adult specimen
6 A dorsal valve
7 Internal cast of large ventral valve
Locality: Ponta Grossa, Brazil
8 Internal cast of dorsal valve
Locality: Jaguariahyva, Brazil
9 Dorsal cast
Locality: Cold Bokkeveld, Cape Colony

Coelospira ? colona Clarke

Fig. 10, 11 Ventral valves. x 2
12, 13 Ventral and dorsal views. x 2
Locality: Ponta Grossa, Brazil

Leptostrophia ?? mesembria Clarke

Fig. 14 Exterior of ventral with internal cast of dorsal valve
15 Sculpture cast showing dorsal aspect
Locality: Fox bay, West Falkland
16 Enlargement of hinge structure showing incipient denticles or spinules on cardinal line
17 Internal cast of ventral valve
Locality: Ponta Grossa, Brazil
18 Internal ventral cast
Locality: Jaguariahyva, Brazil

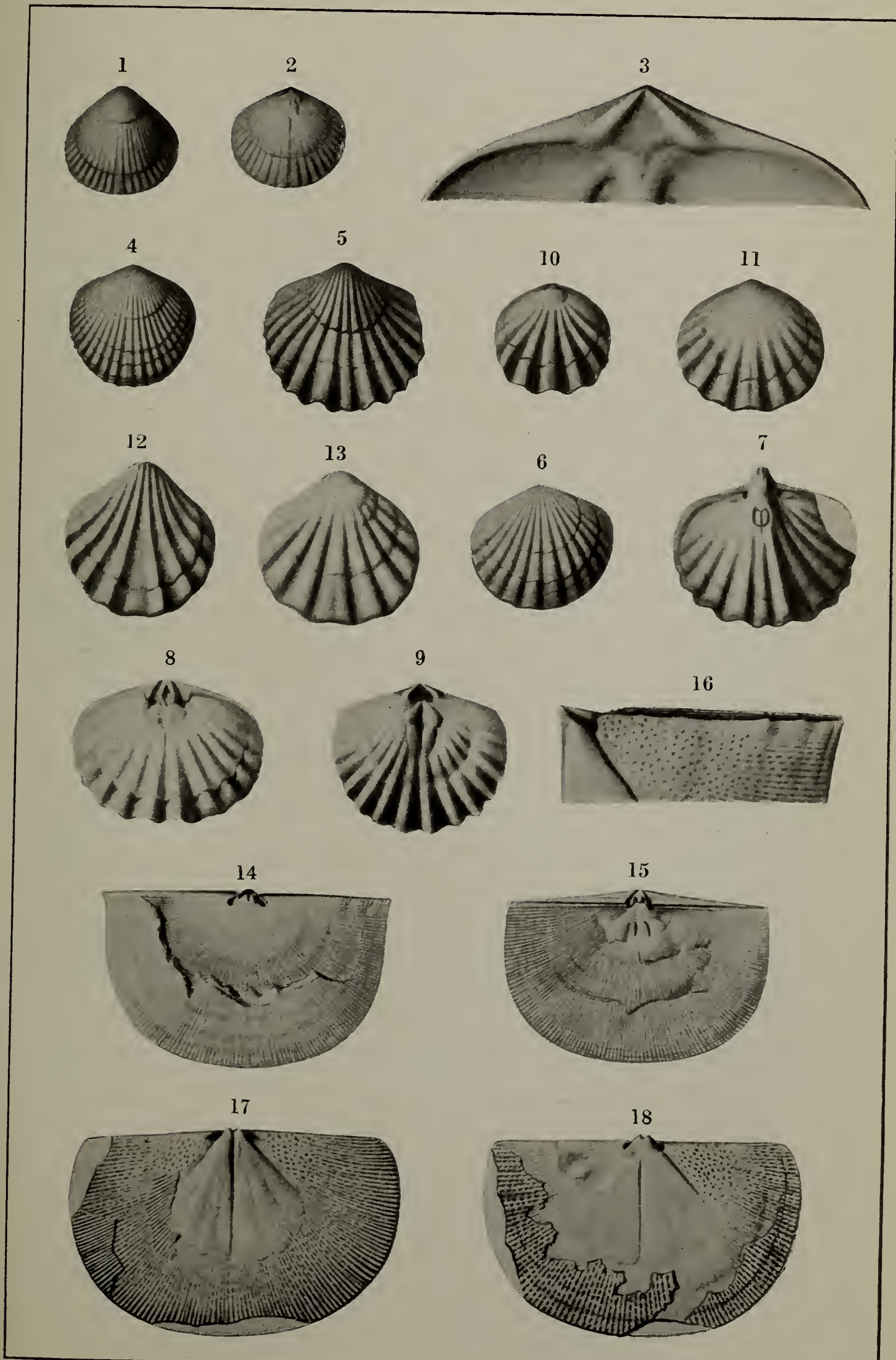
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Plate 28

Leptostrophia concinna (Morris & Sharpe)

Fig. 1 Internal cast of ventral valve
2 Interior of dorsal valve
3 Internal cast of ventral valve
Localities: Port Howard, West Falkland, and Port Louis, East Falkland

Schuchertella agassizi (Hartt & Rathbun)

Fig. 4 Two characteristic examples showing dorsal aspect only
5 Interior of ventral valve
6 A large and rather short hinged example
7 Internal cast of ventral valve
8 Interior of dorsal valve
Locality: Ponta Grossa, Brazil

Schuchertella sulivani (Morris & Sharpe)

Fig. 9 Internal cast of a ventral valve
Locality: Fox bay, West Falkland
10 Internal cast of dorsal valve
11 Interior of dorsal valve
12 Exterior of ventral valve
13 Dorsal aspect of conjoined valves
Locality: Ponta Grossa, Brazil

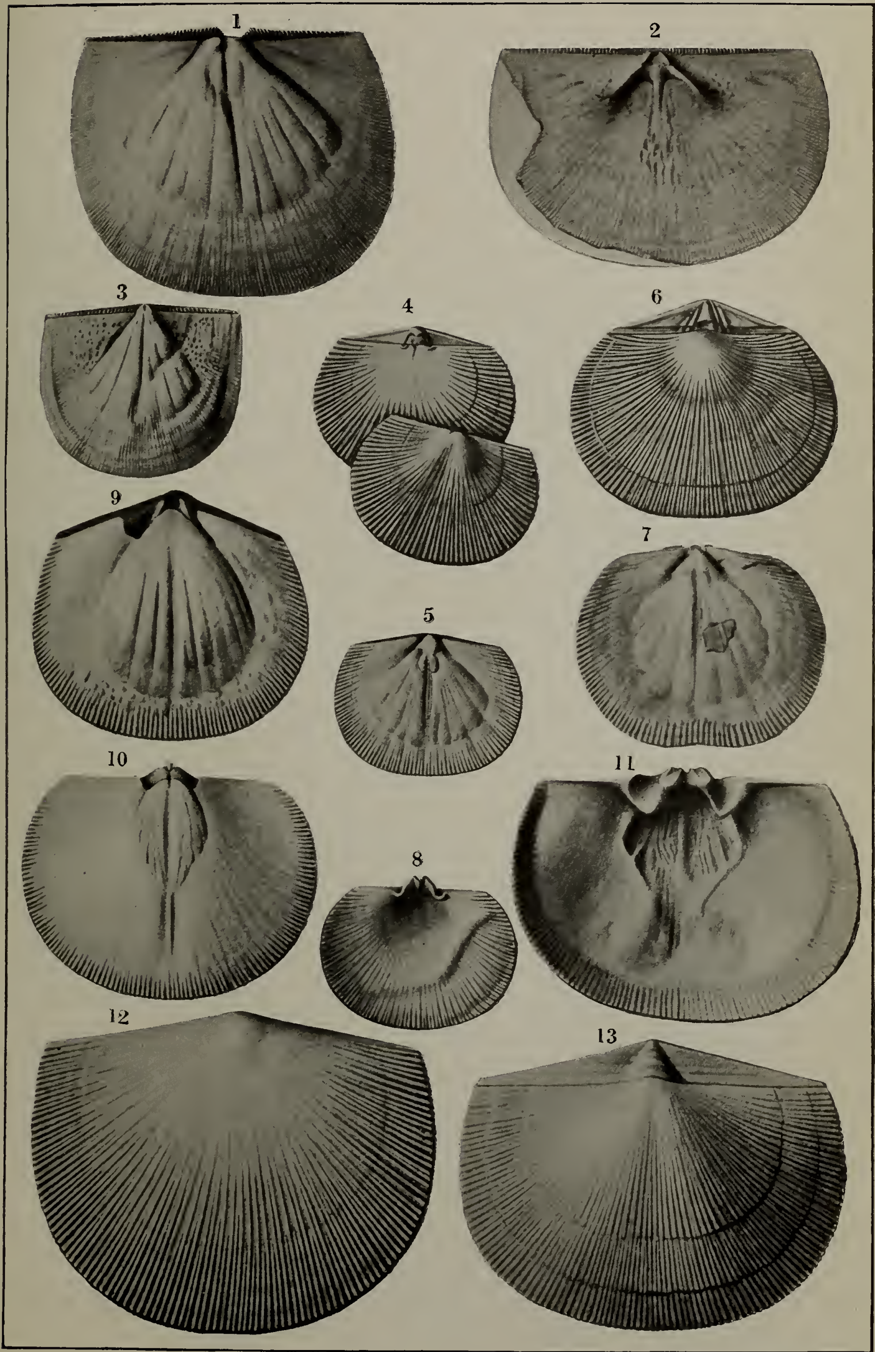
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Plate 29

Chonetes falklandicus Morris & Sharpe

Fig. 1–8 A series of views of this species showing its somewhat variable characters. Figures 1, 2, 3 are from Port Louis, East Falkland; figures 5, 7 from Ponta Grossa; figure 6 is the variety rugosa from Ponta Grossa; figures 4, 8 from Jaguariahyva

Chonetes skottsbergi Clarke

Fig. 9 Dorsal aspect of internal cast

10, 11 Internal casts of ventral valve

12 Interior of dorsal valve

Locality: Port Salvador, West Falkland

Schuchertella sancticrucis Clarke

Fig. 13, 14 Internal casts of dorsal and ventral valves

Locality: Santa Cruz, state of São Paulo, Brazil

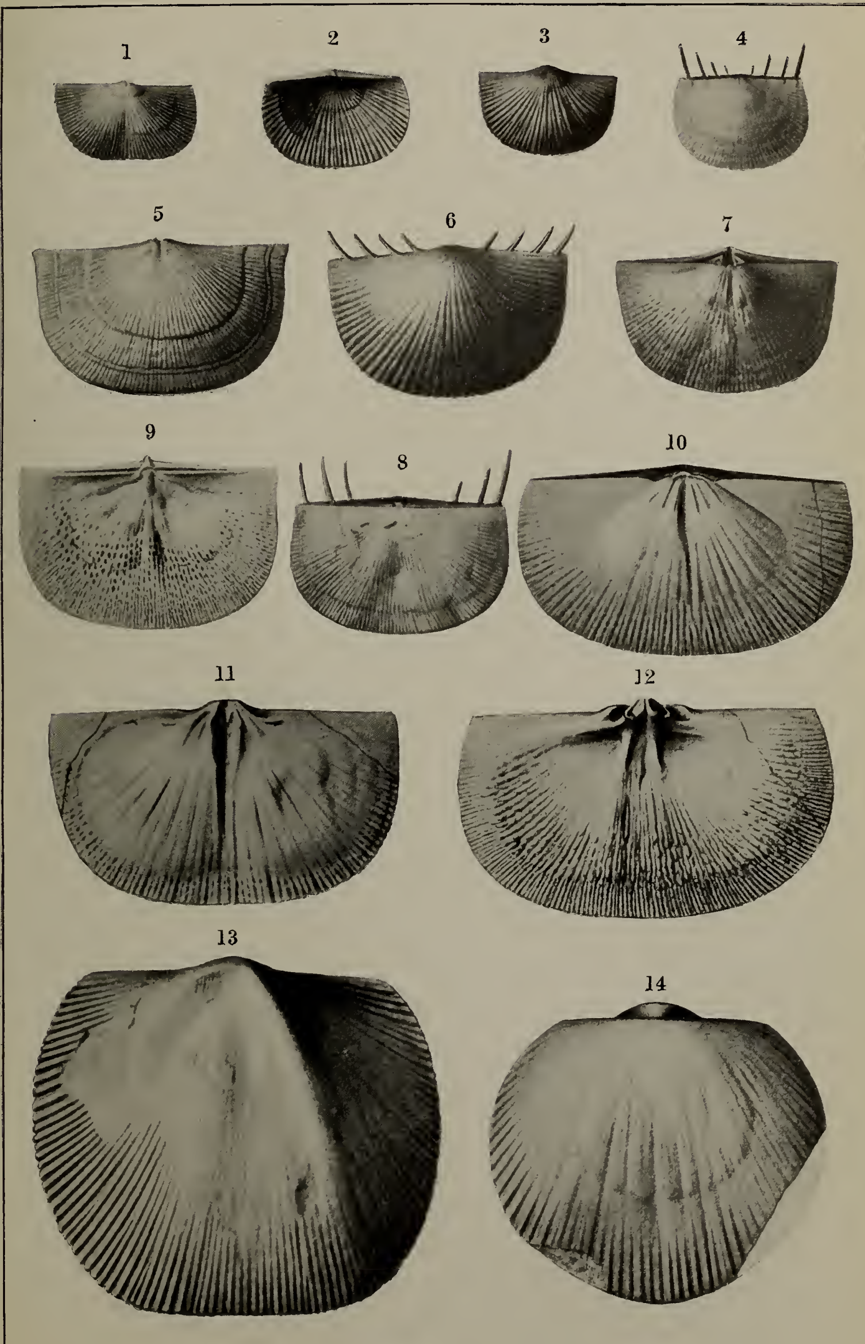
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Plate 30

Chonetes hallei Clarke

Fig. 1 Internal cast of conjoined valves
Locality: Spring Point, Falkland islands

Schizobolus truncatus Hall

Fig. 2, 3 Brachial and pedicle valves. x 3
Locality: Upper Devonic black shale of Ereré, Pará

Orbiculoidea baini (Sharpe)

Fig. 4, 5 Pedicle valves, exterior and interior surfaces
6, 7 Pedicle and brachial valves. x 2
8 Enlargement of surface of pedicle valve
Locality: Ponta Grossa, Brazil

Orbiculoidea bodenbenderi Clarke

Fig. 9, 10 Brachial valves
11 Pedicle valve
12 Enlargement of surface of pedicle valve
Locality: Ponta Grossa, Brazil

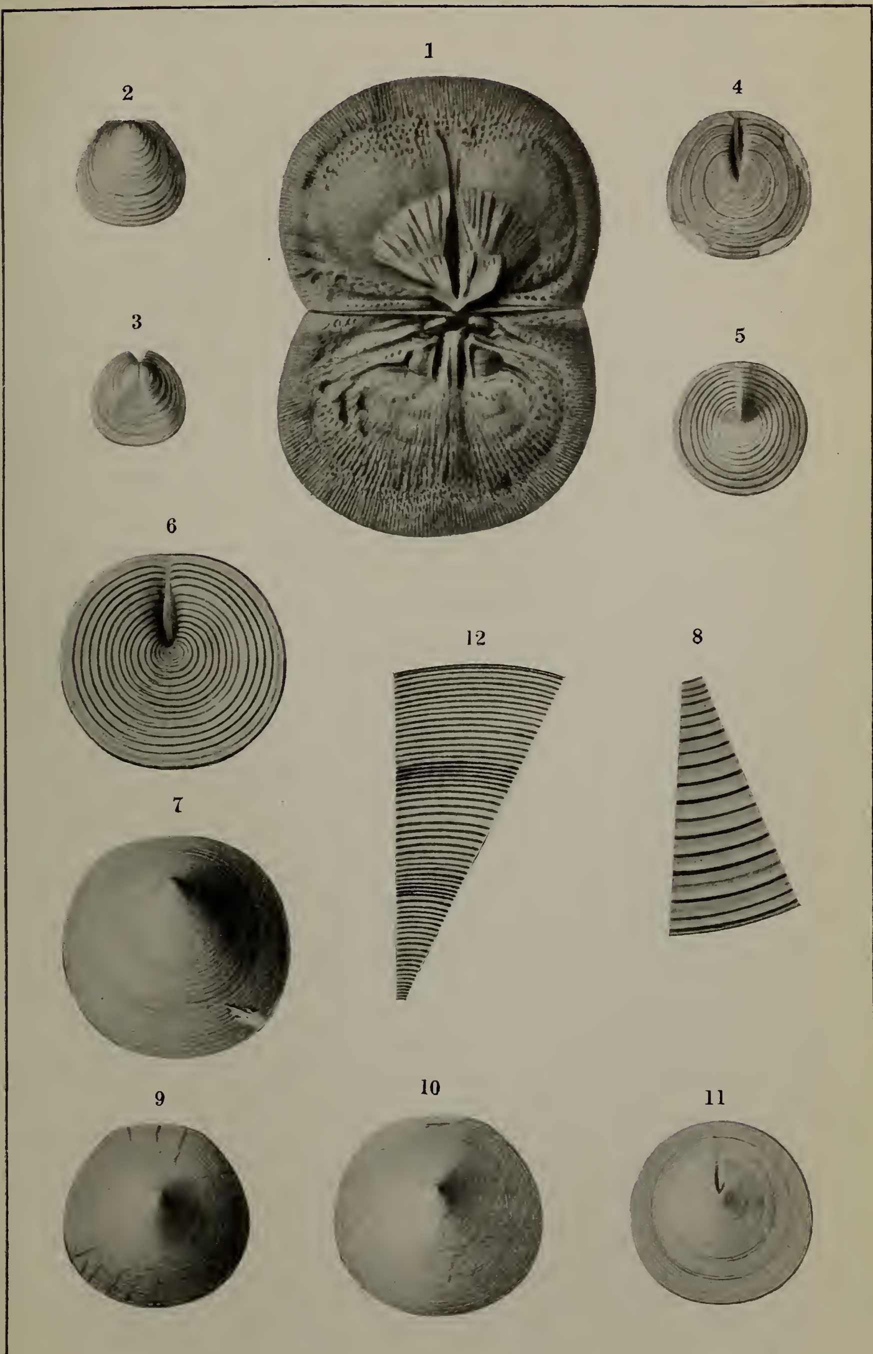
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Plate 31

Orbiculoidea collis Clarke

Fig. 1 Exterior of pedicle valve
2, 3 A brachial valve and its profile
Locality: Ponta Grossa, Brazil

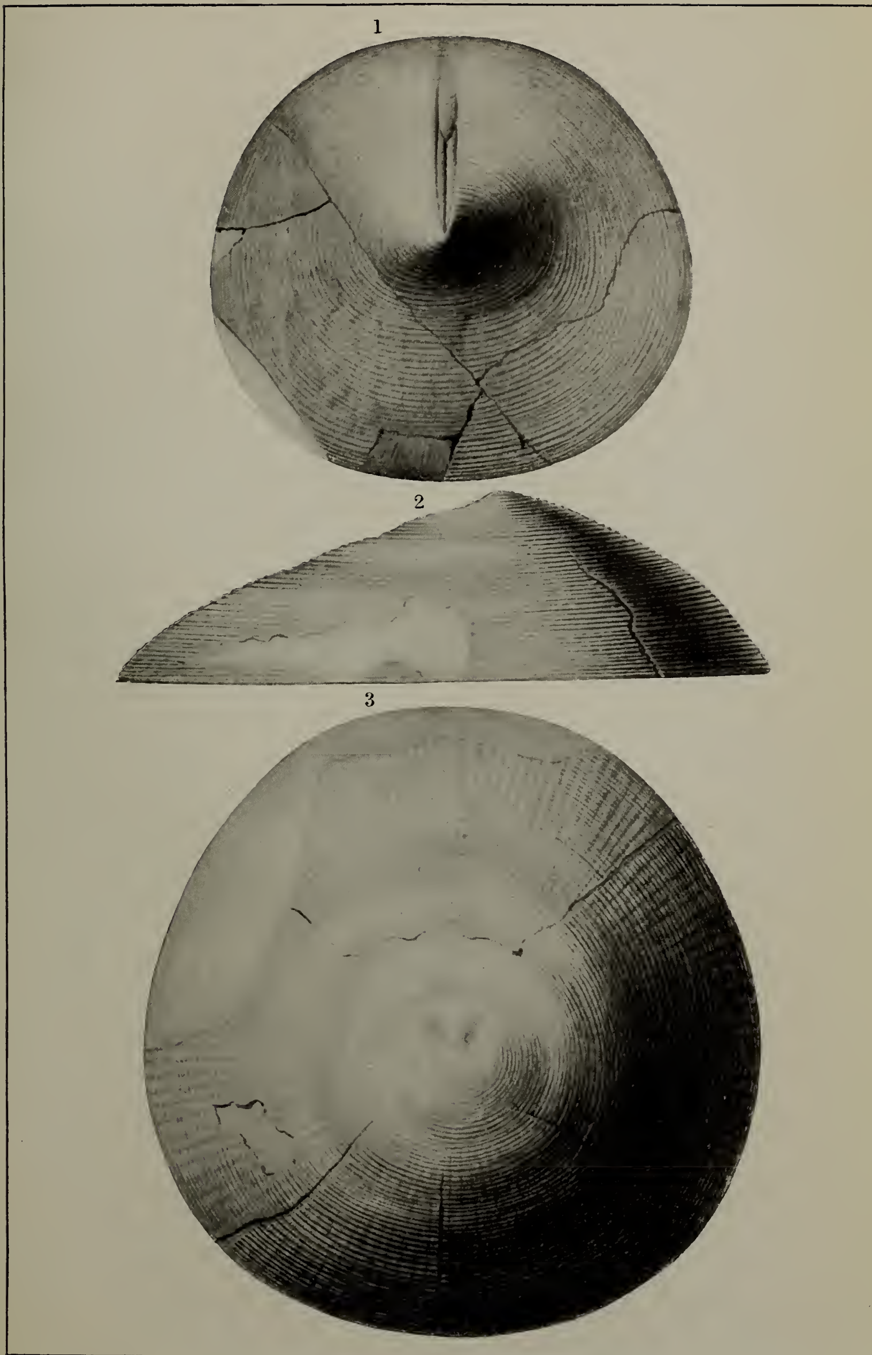
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Plate 32

Lingula scalprum Clarke

Fig. 1, 2 Dorsal and ventral valves
Locality: Ponta Grossa, Brazil

Lingula lepta Clarke

Fig. 3, 4 Valves showing outline and muscular scars
Locality: Ponta Grossa, Brazil

Lingula keideli Clarke

Fig. 5, 6 Ventral and dorsal valves
Locality: Ponta Grossa, Brazil

Lingula lamella Clarke

Fig. 7 Conjoined valves
8 Dorsal valve with trace of median septum
Locality: Ponta Grossa, Brazil

Lingula subpunctata Knod

Fig. 9 Cast of ventral umbo showing pedicle slit

Problematicum

Fig. 10 Figure of a round cystoid body with a submarginal perforation or puncture from which radiates a pustular ornament. x 2
Locality: Jaguariahyva, Brazil

Clionolithus priscus McCoy

Fig. 11 A series of clavate tubes of this boring sponge in a shell of Ptomatis moreirai. x 1.5
Locality: Ponta Grossa, Brazil

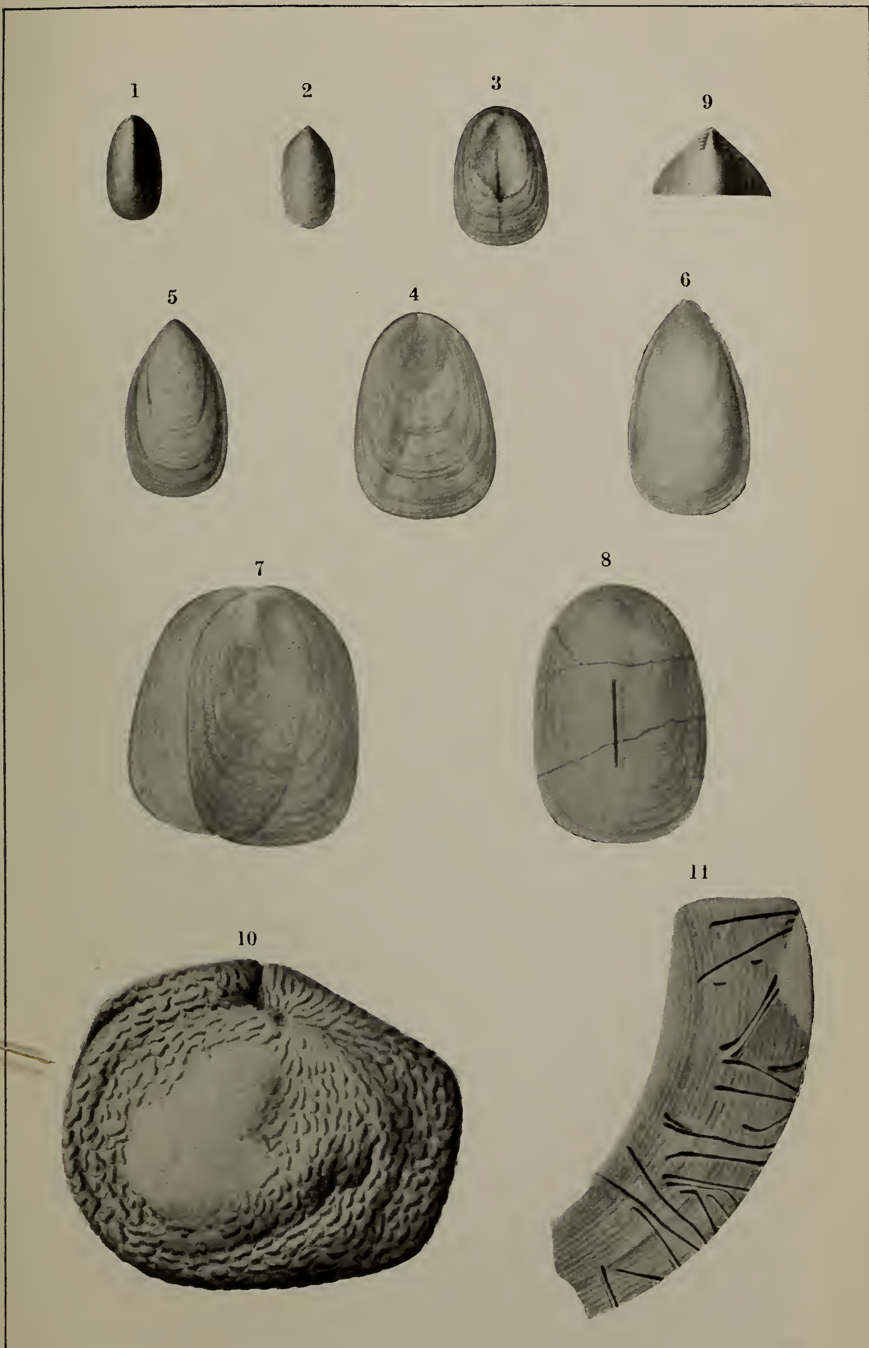
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Plate 33

Serpulites sica Salter

Fig. 1 Portions of flattened chitinous tubes with thickened edges
Locality: Ponta Grossa, Brazil

Plant (or branched annelid?)

Fig. 2 A frond or colony on which the branches are flattened clavate tubes taking origin from a clavate stipe. x 1.5
Locality: Ponta Grossa, Brazil

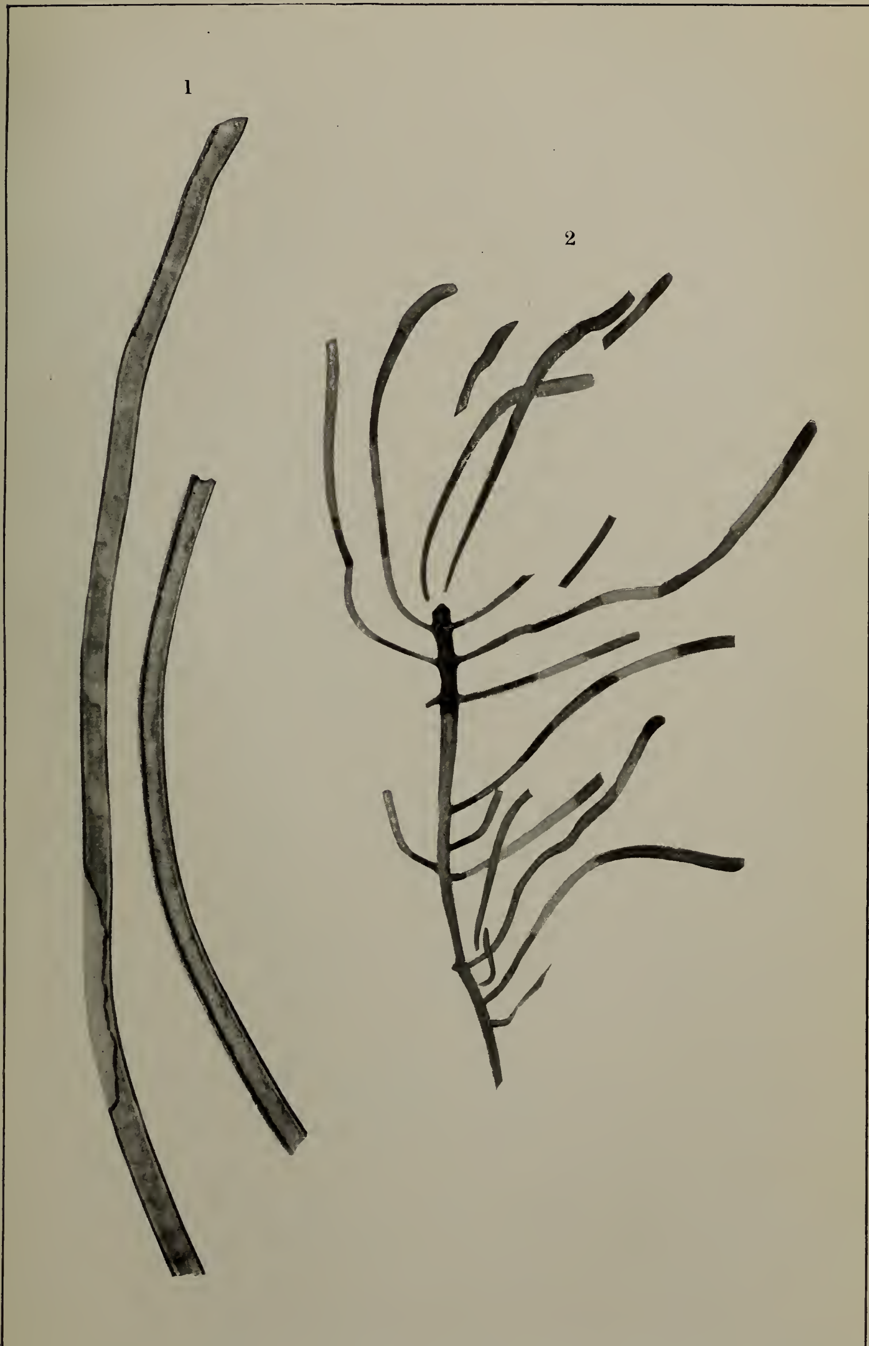
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Plate 34

Echinasterella? darwini Clarke

Fig. 1 Oral surface of an essentially entire specimen
2 Enlargement of part of arm
3 Madrepore plate. x 3
Locality: Ponta Grossa, Brazil

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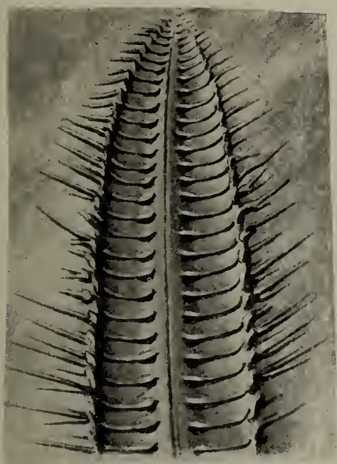

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Plate 35

Aspidosoma ? pontis Clarke

Fig. 1, 2 Clusters of individuals in the soft shale, all exposing the ambulacral face

3 The entire oral apparatus. x 3

4 Part of oral frames and teeth. x 5

Locality: Ponta Grossa, Brazil

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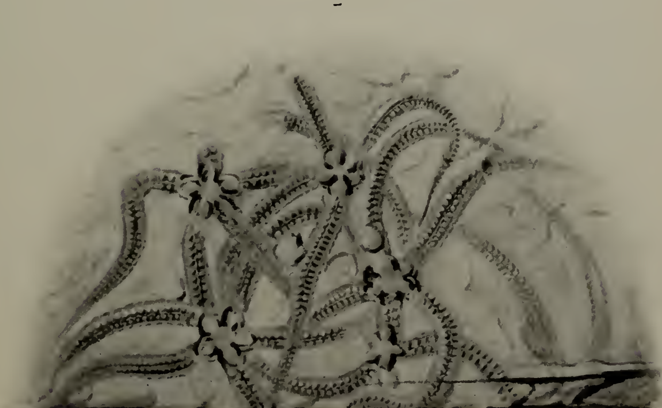

INDEX

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Published fortnightly

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New York State Museum

John M. Clarke, Director

Museum Bulletin 168

THE GEOLOGICAL HISTORY OF NEW YORK STATE

BY

WILLIAM J. MILLER

New York State Education Department
Science Division, February 28, 1913

Hon. Andrew S. Draper LL.D.
Commissioner of Education

SIR: I have the honor to submit herewith, and to recommend for publication as a bulletin of the State Museum, a manuscript entitled *The Geological History of New York State,* which has been prepared at my request by Dr William J. Miller, a member of the expert staff of this Division.

This work brings together in compact for a resumé of the geological events in the development of the State, and for such a publication as this there is at the present time a widespread demand.

Very respectfully
JOHN M. CLARKE
Director

STATE OF NEW YORK
EDUCATION DEPARTMENT
COMMISSIONER'S ROOM

Approved for publication this
17th day of March 1913

Commissioner of Education

Taughannock Falls (height 215 feet) which ranks as the highest true waterfall in New York State. Located near Trumansburg, Tompkins county. The rocks are Devonic sandstones and sandy shales and the postglacial gorge just below the falls is nearly 400 feet deep.

Photo loaned by H. R. Head, Ithaca, N. Y.

University of the State of New York Bulletin

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Published fortnightly

No. 557 ALBANY, N. Y. DECEMBER 15, 1913

New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 168

THE GEOLOGICAL HISTORY OF NEW YORK STATE

BY

WILLIAM J. MILLER Ph.D.

PREFACE

The researches and truths of any modern science if they are properly to fulfil their mission, should be brought within the reach of laymen. In this bulletin the purpose is to present in a simple, readable form, an outline of the wonderful story of the physical development of New York State. No knowledge of physiography or geology is presupposed. Any person who possessed of intelligence and a willingness to learn is fully prepared to read these pages.

When the reader has gained a fair understanding of the principles here set forth, he will be much better prepared to use intelligently the publications of the New York State Museum which deal with the geology and geography of many portions of the State. In short, this volume may be considered as a "first book" for all who are interested in the physical features of our State and it is believed that teachers and older pupils in geography and physical geography may receive helpful suggestions from it.

It must be clearly understood that scarcely more than a sketch of such a large subject can be given in so brief a space. Local details can seldom be brought in except for illustration of certain important points, and of necessity many questions will occur to readers interested in the natural features of their home regions which are not directly answered. It is hoped, however, that most of the important and striking geographic features in all parts of the State are explained, and that many local details will find ready explanation by the application of the principles set forth.

Emphasis is here placed upon the genesis of geographic forms. It is one thing merely to state a geographic fact, such as the location of a mountain or lake or valley, but it is a far different thing to explain how the mountain or lake or valley came to be there. Every geographic form has a history, and if we fail to appreciate that history we lose the most interesting and valuable part of our geographic training. Geographic facts, like all others, are more easily understood and remembered when the reasons for their existence are given, yet it must be admitted that the teaching of such rational geography is still in its infancy in the schools of this State.

The use of a certain number of scientific terms is unavoidable in practice, but common terms only are employed and in every case these are carefully explained when first used in the text. Particular attention is directed to the photographs, maps and diagrams, all of which have been carefully selected or made for the express purpose of illustrating this text. Except for some quotations, references to original papers have been omitted, but at the end of the volume a list of the more important books and papers of general interest is given, and anyone desiring to broaden into wider fields or greater details can readily do so with the aid of those references.

I have used many personal observations made during travels into almost every county of the State, but obviously the book could never have been written were it not for scores of devoted men of science who, during the last hundred years, have zealously labored to unravel the natural history of our great Commonwealth. I gratefully acknowledge my indebtedness to them all.

I am under particular obligation to Dr J. M. Clarke, our able and efficient State Geologist and Director of Science, for his kindness in critically reading the manuscript and making important corrections and suggestions.

W. J. M.

Hamilton College, Clinton, N. Y.

Chapter 1

INTRODUCTION

GENERAL PRINCIPLES AND REFERENCE TABLES

Few states present a more wonderful variety of physical features or afford a more excellent opportunity to those interested in the study and teaching of geography or geology than does New York. Here are rock formations of all the more important types; all the leading types of mountains (Adirondacks, Catskills, and Taconics) except actual volcanoes, and even true lavas occur in the Adirondacks and in the Palisades of the Hudson; hundreds of lakes of various shapes and kinds; shore outlines ranging from the great sand bars and beaches of Long Island to wave-worn cliffs along the shores of Lake Erie and Lake Ontario; typical prairie plains like that south of Lake Ontario; a great plateau in the southwestern region; valleys and gorges of varied origin; rivers of all types and often with remarkable histories; a striking display of relief features; and extensive and varied deposits of glacial origin. Accordingly, it is not an exaggeration to say that examples of nearly all the most important physical features of the earth are represented within the borders of this State.

As the observer looks out over the State he sees this great variety of physical features and, unless he has given some thought to the subject, is very likely to regard these as practically unchangeable, and that they are now essentially as they were in the beginning of the earth's history. Some of the fundamental ideas taught in this book are that the physical features of the State, as we behold them today, represent but a single phase of a very long continued history; that significant changes are now going on all around us; and that we are able to interpret the geography of the present only by an understanding of its changes in the past.

Geology is concerned with the evolution of the earth and of its inhabitants, as revealed in the rocks. This science is very broad in its scope and treats of the processes by which the earth has been, and is now being, changed; the structure of the earth; the stages through which it has passed, and the development of the organisms which have lived upon it.

Geography deals with the distribution of the earth's physical features, in their relation to each other, to the life of sea and land and human life and culture.

Geography is the outward and present expression of geological effects. The terms geography and geology are thus here used in the sense that the latter includes the former, as the cause includes the effect. *Paleogeography* has reference to the geography of the past epochs in the history of the earth.

Physiography, or physical geography, deals with the configuration (relief) of the earth's surface and how it was produced.

As a result of the work of many able students of earth science during the past hundred years, it is now well established that our planet has a clearly recorded history of many millions of years, and that during the lapse of those eons revolutionary changes in geography have occurred; that there has also been from an early stage of the earth's history a vast succession of living beings which have gradually passed from simple into more complex forms and have, in some particulars, reached their highest expression in the organisms of the present time. The geographic changes and the organisms of the ages gone by have left us no abundant evidence of their character and the study of the rock formations has shown that within them we have a fairly complete record of the earth's history.

In the time of Alexander von Humboldt, less than one hundred years ago, the keen student of natural phenomena could carry in his own mind most of what was definitely known of earth history. Today, because of the tremendous growth of the science, it would be a presumption for any man to claim that he knows all of what has been learned about the geological history of even the single State of New York. While it is true that much yet remains to be learned of this old earth, it is a real source of wonderment that man, through the exercise of his highest faculty, has come to know so much about it.

All the rocks of the earth's crust may be divided into three great classes: *igneous, sedimentary,* and *metamorphic.*

Igneous rocks comprise all those which have ever been in a molten condition, and of these we have the volcanic rocks (for example, lavas) which have cooled at or near the surface; plutonic rocks (e. g., granites) which have cooled in great masses at considerable depths below the surface; and the dike rocks, which when molten have been forced into fissures of the earth's crust and there cooled.

Sedimentary rocks comprise all those which have been deposited under water (except for some wind-blown deposits) and are nearly always arranged in layers (stratified). These rocks may be of mechanical origin, such as clay or mud which hardens to shale; sand, which consolidates to sandstone; and gravel, which when cemented becomes conglomerate. Or they may be of organic origin, such as limestone which is formed by the accumulation of calcareous shells; flint and chert, which are accumulations of silicious shells; coal, which is formed by the accumulation of partly decayed vegetable matter. Or, finally, they may be formed by chemical precipitation, as beds of salt, gypsum, bog iron ore, etc.

Metamorphic rocks comprise both sedimentary and igneous masses which have been greatly changed from their original condition. Thus, under conditions of great pressure and heat, with superheated moisture, sedimentary rocks may become crystalline, as when shale is changed to schist, sandstone to quartzite, or limestone to marble; or an igneous rock may take on a banded structure, due to a rearrangement of its component minerals, and thus become a gneiss.

To the modern student of earth science, the old notion of a "terra firma" is outworn. That idea of a solid, immovable earth could never have emanated from the inhabitants of an earthquake country. In the recent San Francisco earthquake, along a line of several hundred miles, one portion of the Coast Range mountains slipped from two to twenty feet past the other. In Alaska, in 1899, a portion of the coast was bodily elevated forty-seven feet. In Japan in 1891, for a distance of forty miles along a rift in the earth's crust, there was a sudden movement of from two to twenty feet. These are merely striking instances of many of the sudden earth movements of recent years. Hundreds of earthquakes occur yearly in the islands of Japan alone, and it is probably true that the earth is shaking all the time.

There are still other movements which are taking place more slowly and quietly, but which are more significant for our interpretation of the profound geographic changes which have occurred during the millions of years of known earth history. Thus the coast of Norway is rising while that of northern France is sinking. Distinct beaches at different elevations far above the ocean level on the western slope of the southern Andes testify to important changes of level in comparatively recent time. A fine illustration of notable sinking of the land is proved by the drowned character of the lower Hudson valley, and by the fact that the old Hudson channel has been definitely traced, as a distinct trench in the ocean bottom, for one hundred miles eastward from Sandy Hook. That this same region has still more recently been partially re-elevated is indicated by the presence of very young stratified beds of clay and sand which are now raised from seventy to three hundred feet above the river, the elevation increasing northward toward Albany. Actual surveys show that, in the Great Lakes region, a differential movement of the land is now in progress, the elevation being greater toward the north.

In the succeeding pages evidence will be offered to show that most of New York State has been repeatedly covered by ocean water. It will also be established that where such mountain ranges as the Appalachians, Alps or Himalayas now exist was formerly ocean bottom upon which layers of sediment were being spread out. Those layers of sediments have been bent, crumpled, folded, and greatly elevated above sea level. Thus it is literally true that the great typical mountain ranges of the earth have been born out of the ocean.

Among other important processes of nature which have long been active in modifying the earth, are those of *weathering* and *erosion*. Weathering is brought about by the various atmospheric agencies such as moisture, oxygen, carbonic and other acids, together with changes of temperature, and the result is to cause all rock masses to disintegrate or decay. In this way most soils are produced, and were it not for the process of erosion, soils would be much deeper and more widespread than they now are. Weathering prepares the material which is carried away by the streams, and this transported material is deposited either along the flood plains of the lower stream courses or on the bottom of the lake or ocean into which the streams flow. Every stream, at time of flood, is heavily charged with mud or even coarser sediment which has been derived from the wash of the land of its drainage basin. The very presence of the sediment in the streams proves that the land is being lowered and although, on first thought, it may be supposed that no really great change could be accomplished by this means, nevertheless we must remember that nature has practically infinite time at her disposal so that slowly but surely vast geographic changes are wrought and, perchance, a tremendous canyon like that of the Colorado in Arizona will be carved out by weathering and erosion. The general tendency is for all land masses to wear down to or near sea level and, were it not for renewed uplifts, all land, even including mountain ranges, would long ago have been worn down to near sea level, that is to the condition of *peneplain* (almost a plain). The former lofty Appalachians were thus worn down to the condition of a peneplain which has since been somewhat rejuvenated by elevation. Accordingly, that familiar expression "the everlasting hills" is much more exact when made to read "the everlastingly changing hills."

Still another important process by which the physical features of the earth have often been changed is through *vulcanism*, or

igneous activity in general. By this means materials are brought up from within the earth to or near its surface. Thus an active volcano violently ejects rock fragments, dust etc. or more quietly pours out molten rock, while in many cases great masses of molten rocks have been forced upward into the crust of the earth without reaching the surface and hence have slowly cooled at greater or lesser depths below the surface. Such volcanic rocks have become exposed to view only by subsequent erosion of the region.

In order to understand the physical history of our State it is necessary to know that significant changes, like those above described, have long been, and now are taking place. In tracing this history we shall see how all these natural processes have operated to bring the State into its present condition. It is also necessary to understand that the known history of the earth has been carefully divided into great eras, and into lesser periods and epochs, and that these constitute what is called the geologic time scale. This time scale is important to the reader because the principal events in the history of the State will be taken up, so far as they are recorded, in regular order according to that scale. In the first table the names of eras and periods are mostly of world-wide usage, while the names of subdivisions (epochs) of the periods are much more local in usage and, in the second table, only those are given which apply to New York State.

Geologic Time Scale

ERAS	PERIODS	DOMINANT LIFE
Cenozoic	Quaternary	Age of man
	Tertiary	Age of mammals
Mesozoic	Cretacic Jurassic	Age of reptiles, with birds first in the Jurassic, and trees and flowers of modern aspect first in the Cretacic
	Triassic	Age of amphibians, with cycad plants common
Paleozoic	Permic	
	Carbonic	Great coal age, with large nonflowering plants
	Devonic	Age of fishes
	Siluric Ordovicic Cambric	Age of invertebrates, with some very simple fishes in the Siluric
Proterozoic	Algonkic	Earliest known forms of life but records very imperfect
Archeozoic	Archean	

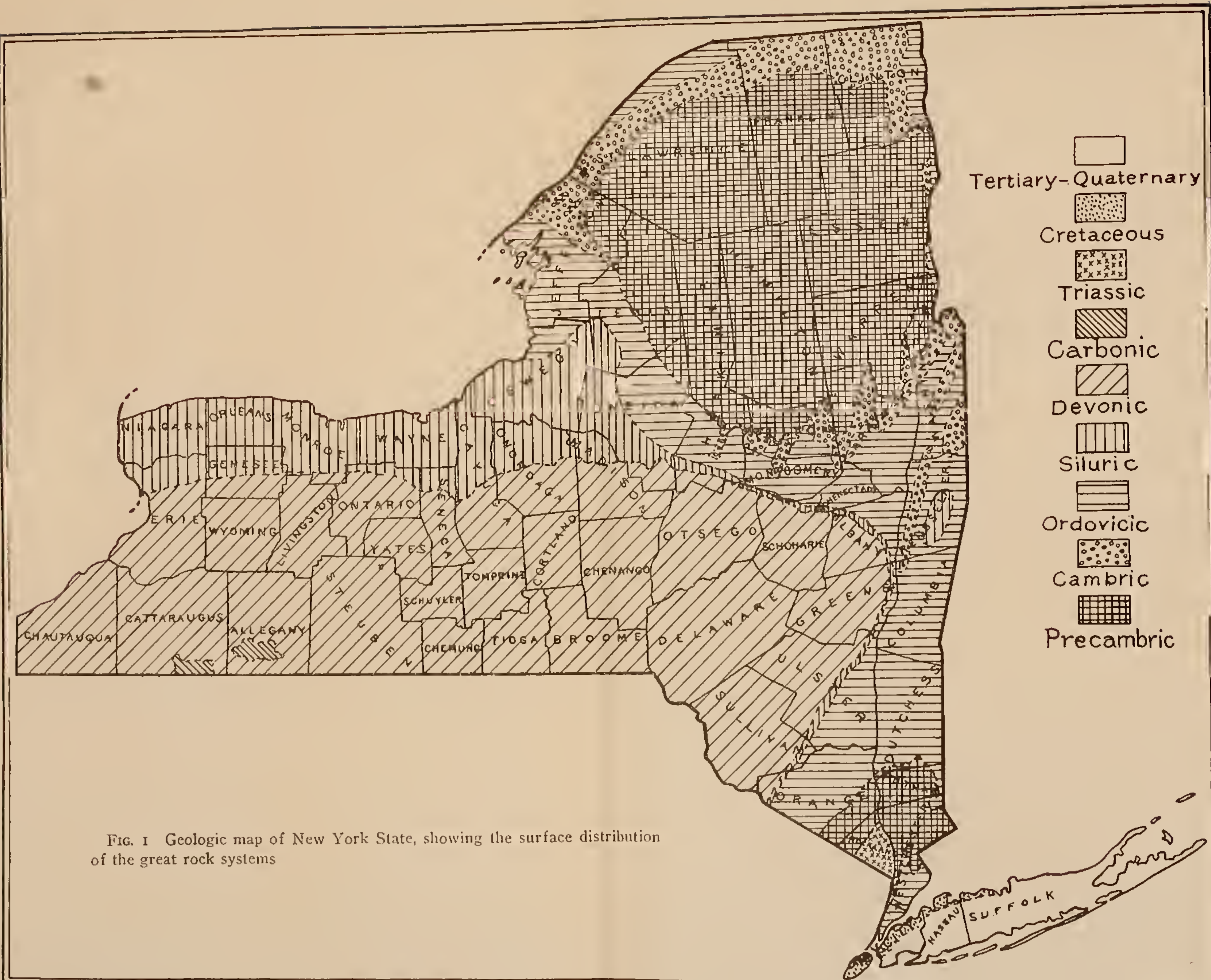


FIG. 1 Geologic map of New York State, showing the surface distribution of the great rock systems

PERIODS, EPOCHS, AND ROCK FORMATIONS IN NEW YORK STATE

Period	Epochs and formations	Distribution
Quaternary	Recent clay beds, alluvium etc. Pleistocene. Glacial clay, sand, gravel, boulders etc.	Surface deposits very common over the State
Tertiary	Pliocene Miocene	Sands, clays, and gravels on Long Island
Cretacic	Monmouth Matawan Magothy Raritan	Clay and sand on Long and Staten Islands
Jurassic	Absent (probably)	
Triassic	Newark sandstone and Palisade lava	Rockland county
Permic	Absent	
Carbonic	Olean conglomerate Cattaraugus shale	Allegany and Cattaraugus counties
Devonic	Catskill and Chemung sandstones	Catskills and southwestern New York
	Portage shale and sandstones	South-central and western New York
	Genesee shale Tully limestone	East-central to western New York
	Hamilton shale Marcellus shale Onondaga limestone Oriskany sandstone Helderberg limestone	East-central to western New York and eastern base of Catskill mountains
Siluric	Manlius limestone Rondout waterlime Cobleskill limestone Salina shales, salt, waterlime and Shawangunk conglomerate	Eastern to western New York except Shawangunk in eastern New York only
	Lockport and Guelph dolomites Rochester shale	Central to western New York
	Clinton shale, sandstone, limestone and iron ore	Central to western New York
	Medina and Oneida sandstone and conglomerate	Central to western New York

Ordovicic	Frankfort shale and sandstone Utica shale	Central New York and western side of the Adirondacks
	Trenton limestone and shale Black river limestone Chazy limestone Beekmantown limestone	Around the Adirondacks and more or less in Hudson valley. Chazy absent from Mohawk valley
Cambric	Little Falls dolomitic limestone Potsdam sandstone and limestone	Around the Adirondacks and some in southeastern New York
	Acadian limestone Georgian slate and quartzite	East of Hudson river from Washington county southward
Precambric	Igneous series — Anorthosite, granite, syenite, gabbro and diabase Grenville metamorphosed sediments	Adirondacks and Hudson Highlands

Throughout this book the purpose is not merely to describe the physical features of the State, but rather constantly to emphasize the history or evolution of those features. The idea which I would now convey to the reader has been admirably expressed by Professor Davis in his "The Physical Geography of Southern New England": "Geography still retains too much of its old-fashioned, irrational methods: it has not kept pace with the advance made by geology. In spite of what the geologist has learned about the evolution of geographical forms, the geographer still too generally treats them empirically, and thus loses acquaintance with one of the most interesting phases of his subject. . . . It is often maintained that a devoted study of the facts themselves, without regard to their meaning or development, will suffice to place them clearly enough before the mind; but this view is contradicted both by general experience in many subjects where rational explanation has replaced empirical generalization, and by the special experience of geography as well. Left to itself as an empirical study, in which the development of land forms was hardly allowed to enter, it has languished for many years, until it became a subject for continual complaint. . . . Today it is only by those who fail to see the direction of geographical progress, and who are ignorant of the progress already gained, that objection is made against the effort to bring every geographical fact under the explanation of natural processes. No one of active mind can look across our upland and fail to gather increased pleasure and profit from understanding its history. No one who looks upon geography as the study of the earth in relation to man can contemplate the contrast between glaciated New England [or New York] and nonglaciated Carolina without inquiring into the meaning of the contrast: he might as well study the Sahara and the Sudan without asking the reason for the dryness of the one and the moisture of the other."

The highest and most rugged Adirondack topography, as represented by a portion of the Mt Marcy (U. S. G. S.) quadrangle. One of the northeast-southwest ridges so common in the eastern Adirondacks is shown just east of the lakes. The rocks are nearly all of plutonic igneous origin (anorthosite). Scale, about 1 mile to the inch. Those who are not familiar with the topographic map and its interpretation should refer to the explanation in the appendix.

Plate 2

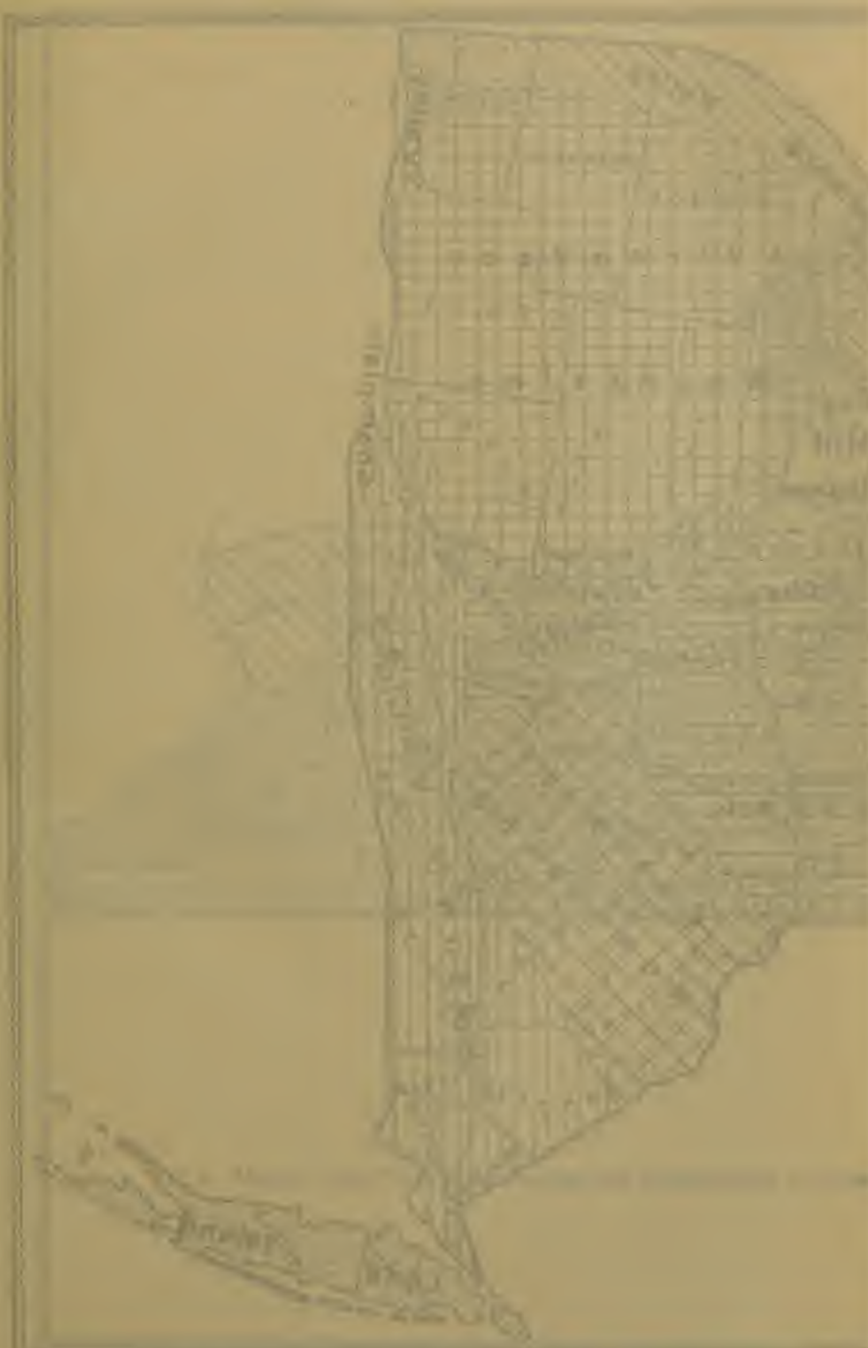
A typical view in the midst of the Adirondacks. Looking across Long lake from Buck mountain, showing Mt Kempshall and Blueberry mountain. Note the flowing outlines of the topography.

From N. Y. State Mus. Bul. 115, pl. 15

Plate 3

General view in the Adirondacks looking northward across Lake Pleasant (Hamilton county). Note the flowing outlines of the topography.

Photo loaned by John A. Cole, Lake Pleasant, N. Y.



Chapter 2

PHYSIOGRAPHIC PROVINCES, STRUCTURE AND DRAINAGE

GENERAL STATEMENT

The area of this State is 49,170 square miles, including 1550 square miles of water. The range in altitude is from sea level to over 5000 feet, while the average elevation is about 900 feet. Mt Marcy (altitude 5344 feet) in Essex county is the highest mountain in the State.

For the sake of convenience in discussing the general physiography and structure, the writer has divided the State into certain well-defined physiographic provinces as shown on the accompanying map. Lest the sharp boundary lines convey a wrong impression, it should be stated that the provinces are, in reality, seldom sharply separated from each other (see figure 2).

ADIRONDACK MOUNTAIN PROVINCE

The Adirondack mountain province comprises fully one-fourth the area of the State and consists of a great, nearly circular mass of metamorphic and igneous rocks of very great age, that is, Prepaleozoic. This large mass of crystalline rocks is completely surrounded by the practically unaltered Cambric and Ordovicic rocks. The whole province is typically mountainous and heavily wooded, often being truly wilderness in character with very few roads or settlements other than summer resorts. Except along the immediate borders, the elevations range from 1000 to over 5000 feet. The greatest axis of elevation extends from southern Hamilton county (2000 feet) northeasterly well into Essex county where the highest mountains are grouped around Mt Marcy, and where the mountains commonly attain altitudes of from 3000 to 5000 feet (see plate 1). In the eastern and southeastern portions there is a well-defined tendency in the mountain masses to be arranged in long, nearly parallel ridges or " ranges " whose general trend is north-northeast to south-southwest. This structural feature is due to numerous faults or fractures in the earth's crust and will be explained on a later page. In the northern and western portions the mountains are very irregularly arranged. Viewed as a whole there are no high, sharp-topped peaks which stand out prominently above the general mountain level, and the flowing or rounded outline of topography is by far the most common (see plates 2 and 3). The very ancient Grenville rocks occur throughout the

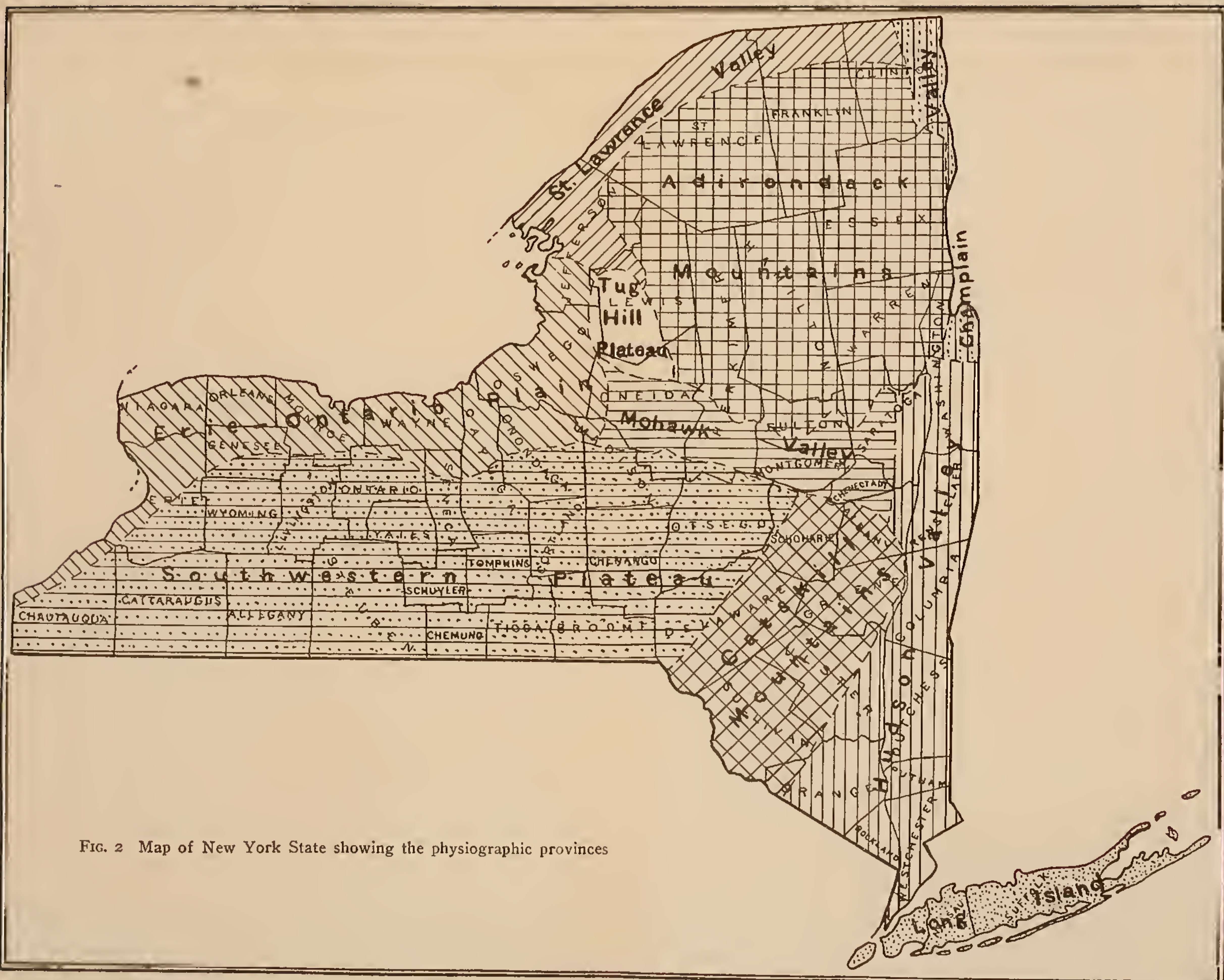


Fig. 2 Map of New York State showing the physiographic provinces

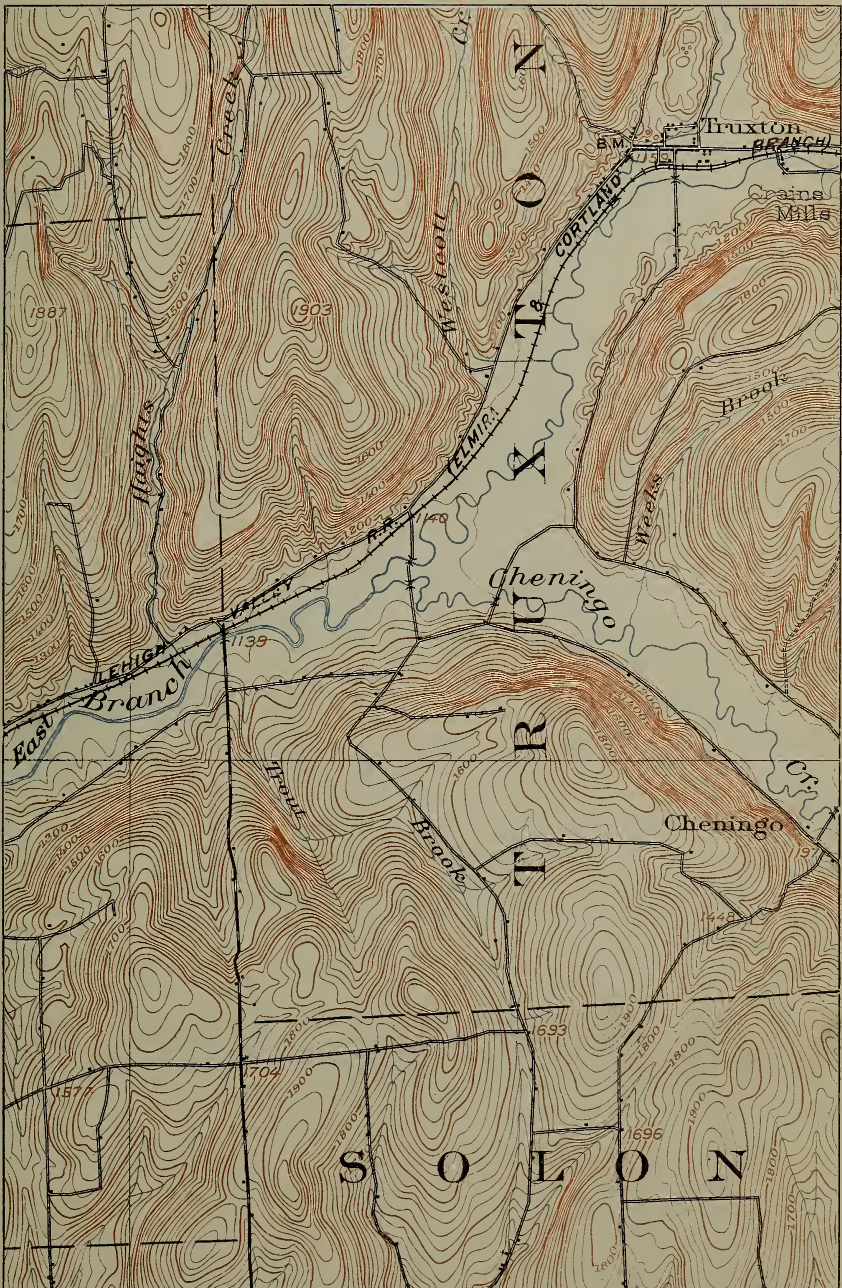
region, and great masses of igneous rocks have been forced through these. All these rocks have been subjected to tremendous earth pressure which has folded and thoroughly metamorphosed them.

SOUTHWESTERN PLATEAU PROVINCE

This, the largest clearly defined physiographic province, occupies nearly one-third of the area of the State. The rocks are all unaltered sediments of Devonic age, except a few small patches of Carbonic rocks in the southwest, and consist of shales, sandstones, and conglomerates. These formations exist as vast sheets or layers piled one upon another, with an aggregate thickness of several thousand feet (see figures 3 and 5). In marked contrast to the Adirondack province, the rock masses of this southwestern plateau are practically devoid of displacements, the only disturbance being a slight tilt (30 to 50 feet a mile) of all the strata to the south or southwest, associated with low northeast-southwest undulation.

Although this plateau is pretty well trenched or dissected by streams, it is nevertheless not a mountainous country, there being no high ranges or peaks standing out prominently. The elevation of the province varies from 500 to 600 feet on the northern side to over 2000 feet on the eastern and western sides. A notable feature is the distinct sagging of the plateau toward the middle portion. This sagged or depressed portion is occupied by the Finger Lakes, especially that portion filled by the south ends of Cayuga and Seneca lakes and the valleys which enter them from the south in the region of Chemung and Tioga counties. It is possible, by traveling along Seneca lake and thence southward to Elmira and the Chemung river, to pass entirely across the plateau province from north to south without attaining an altitude of much over 900 feet, which is on the divide between Watkins and Elmira.

Physiographically, the Plateau province is really but the northernmost extension of the great plateau which lies along the western base of the Appalachian mountains. On the east the province is bounded by the Catskill mountains which are in no sense sharply separated from the plateau itself. On the west and north the province is bounded by the Erie-Ontario plain and Mohawk valley provinces. The northern limit is pretty clearly marked by what is known as the "Helderberg escarpment" of Devonic limestone. This limestone, being of considerable thickness and more resistant than the neighboring formations, has generally stood out boldly against erosion, thus causing an abrupt change in relief. The escarpment is particularly prominent along the boundary of the



Typical southwestern plateau topography. Note the numerous irregular shaped hills, the high general level of the country and the deep broad-bottomed valleys occupied by the larger streams. The rocks are shales and sandstones of Devonic age. From Cortland (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

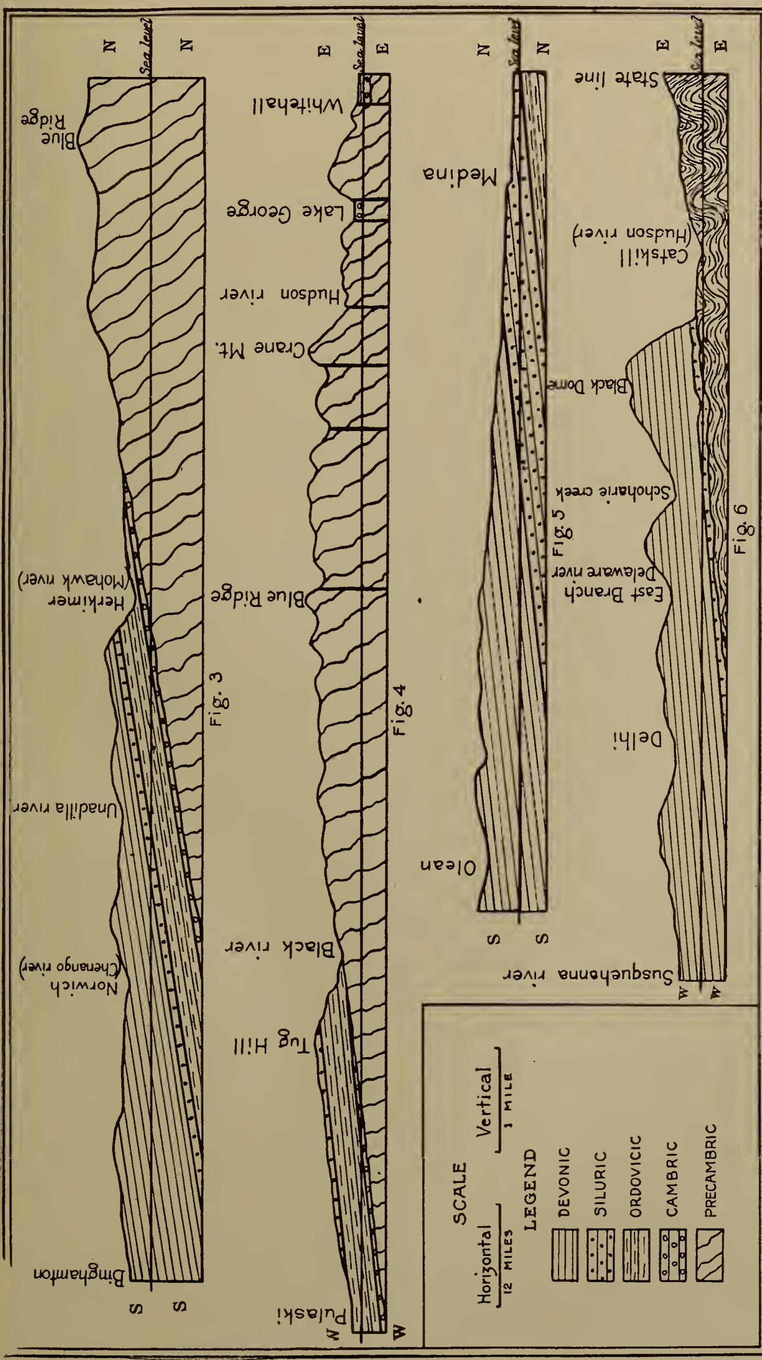


Fig. 3–6 Generalized structure sections through various parts of New York State, showing the attitude and relations of the great rock masses.

plateau and Mohawk valley provinces where the hard limestone lies at an altitude of more than 1000 feet, and directly overlies the soft shales of the valley whose altitude is only a few hundred feet.

CATSKILL MOUNTAIN PROVINCE

This is the most rugged of all provinces in the State and, next to the Adirondacks, contains the greatest elevations. Slide mountain (4205 feet) is the highest, while a number of points range from 3500 to over 4000 feet in altitude.

The rocks are all of Devonic age and consist almost entirely of sandstones and conglomerates. Except for a slight westward undulation, these rocks are arranged in practically horizontal layers and show an aggregate thickness of several thousand feet (see figure 6). Lying under these Devonic rocks and outcropping at the very base of the mountains on the north and east, are various formations of Siluric age.

The term "mountains" as applied to the Catskills requires some explanation. The more typical mountains of the world have been formed by folding or faulting of the strata, or by igneous activity, or by two or all of these causes combined. For example, in the development of the Appalachians both folding and faulting have played prominent parts, while in mountains like the Sierras or Adirondacks, folding, faulting, and igneous action have all been important. The Catskills, however, in which these typical mountain phenomena are wholly lacking, are to be properly placed in the category of what we may call "erosion mountains." Mountains of the pure erosion type are due to an uplift of land high above sea level, followed by deep dissection of the elevated mass by the action of streams. The Catskills are only an easterly extension of the plateau province where the rocks are more resistant and perhaps the elevation of the region was greater, so that the streams were able to cut deeper trenches while the harder rocks of the divides have so far prevented a general wearing down of the region. The Catskills furnish a remarkable example of a high plateau deeply dissected by numerous streams. The whole topography is very rugged, all being much like that of the highest portion of the Adirondacks around Mount Marcy (compare plates 2 and 5). The Catskills, however, lacking the proper structural features, show practically no tendency to parallel arrangement of ridges or mountains as is so common in the Adirondacks.

On the south the Catskill province almost grades into the folded region of the Appalachians, while on the west it gradually merges into the southwestern plateau. On the north the Helderberg

Map of part of the Catskill province showing the high, rugged character of the mountains and the remarkably steep, high eastern front of the province overlooking the great Hudson valley. From the Kaaterskill (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

Plate 6

The pass between Hunter and Plateau mountains in the Catskills. This is a fine example of the deep, steep-sided, V-shaped valleys so characteristic of this province.

From Annual Rep't N. Y. State Geol., 1897, pl. 20, facing p. 282

escarpment, standing out abruptly and to a great height, forms a sharp boundary. On the eastern side the Catskills present a very steep, high front facing the Hudson valley. This steep front rises about 3000 feet and consists of hard Devonic sandstones and conglomerates overlying the Siluric strata (see figure 6).

MOHAWK VALLEY PROVINCE

The Mohawk valley province, though comparatively small, is of great importance because it so clearly separates the Adirondack highlands on the north from the highlands of the Catskills and southwestern plateau provinces on the south. In fact it should be noted that the Mohawk valley is by far the lowest passageway across the mountains between the St Lawrence river and the southern end of the Appalachian range. This low pass is one of the great eastern "gateways" which, with the St Lawrence, have afforded the easiest means of communication between the Atlantic seaboard and the region west of the Appalachian mountains.

The comparatively narrow inner valley through which the river now flows is often erroneously called the Mohawk valley, but in reality the whole depression, from 10 to 30 miles wide and fully 1000 feet deep, between the northern and southern highlands of the State, should be called the Mohawk valley. At Little Falls the inner valley narrows to a gorge several hundred feet deep, where the river has cut its way through a preglacial divide (see plate 7 and figure 7). Had it not been for the recent cutting of this gorge (see explanation accompanying plate 44 in chapter 6) through the barrier at Little Falls, the Mohawk valley would never have been so important as a great gateway between the Atlantic coast and the west. Today the four tracks of the New York Central Railroad, two tracks of the West Shore Railroad, the Erie canal (now being enlarged to the Barge canal), an important highway, many telegraph and telephone wires, and the Mohawk river all pass through this narrow gorge and within a few hundred feet of sea level. Eastward and westward from Little Falls, the inner valley is generally fairly wide and open (see plate 7). At Little Falls the Mohawk river is less than 400 feet above sea level and even at Rome, in the western part of the province, the river shows an altitude of only 420 feet.

The principal rocks of the province are shales, sandstones and limestones of Cambric and Ordovicic ages; of these the soft, black shales of Trenton, Utica, and Frankfort ages are in greatest abundance. The valley owes its existence largely to the presence of this belt of soft shales lying between the hard crystalline rocks of the Adirondacks on the north and the comparatively hard limestones immediately southward. The work of erosion has made rapid progress in this belt of weak rocks, and at two places, Little

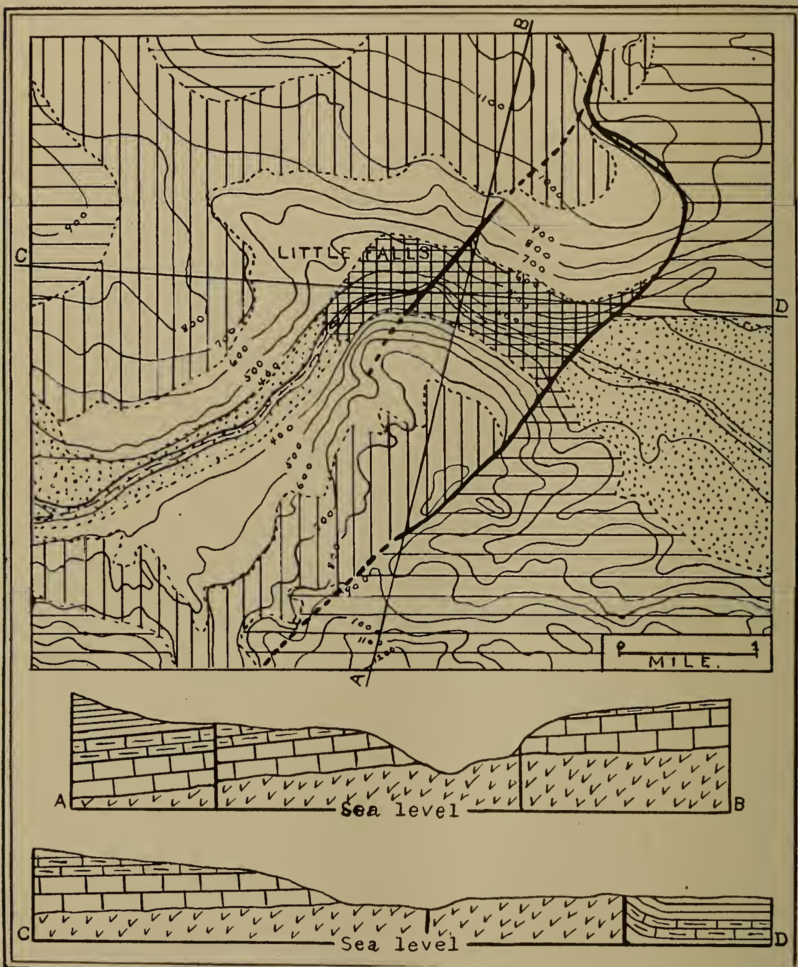
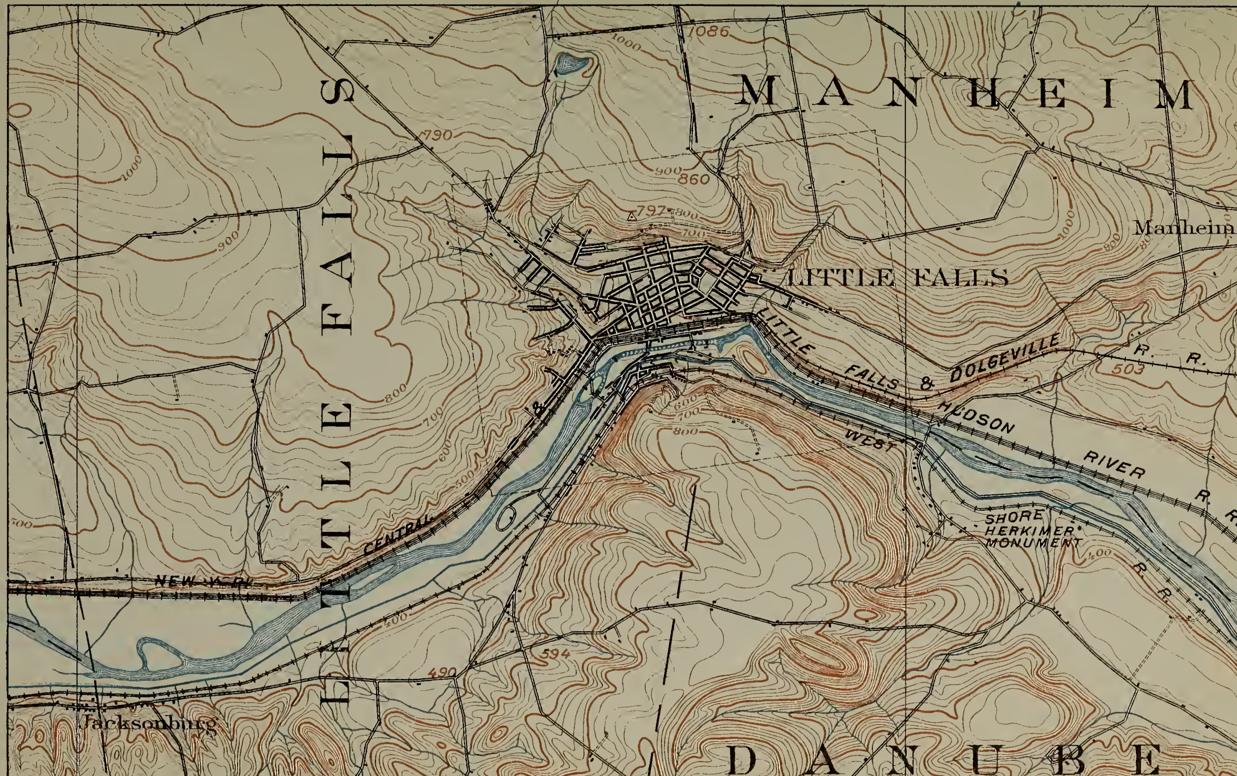


FIG. 7 Geologic and topographic sketch map and structure sections of the vicinity of Little Falls. Crosslined area at bottom of gorge = Precambric rock (syenite); blank areas = Little Falls (Cambric) dolomite; vertical line areas = Trenton (Ordovicic) limestone and shale; horizontal lined areas = Utica (Ordovicic) shale; dotted areas = Quaternary sand and gravel. Heavy black lines are faults. The structure sections show the condition of things along the lines AB and CD. In the sections the vertical scale is four times exaggerated.

Based upon map by H. P. CUSHING



Topographic map showing the deep, narrow gorge of the Mohawk river at Little Falls. The walls of the gorge rise fully 500 feet above the river which is less than 400 feet above sea level. The gorge is postglacial in origin and before the great ice age it was replaced by an important divide with one stream (Mohawk river) flowing eastward and another stream (Rome river) flowing westward. Part of Little Falls (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

Falls and "The Noses" (Yosts), the river has cut down to the Precambric (Adirondack) rock. In general, the rock formations of the province tilt slightly southwestward and show folding only on a very small scale. From Little Falls eastward, however, the strata are greatly disturbed by numerous nearly north-south faults which are often of considerable magnitude (see figure 25).

ERIE-ONTARIO PLAINS PROVINCE

On the extreme western side of the State, and lying between Lake Erie and the Southwestern plateau, there is a strip of land only a few miles wide which may be called the Erie plain. This plain is of very low relief and slopes from an altitude of from 800 to 900 feet down to the level of Lake Erie, whose altitude is 573 feet. Where the Erie plain joins the Southwestern plateau there is a very decided change of slope. The rocks underlying this plain are dark shales of Devonic age and show the usual slight southwestward tilt (see plate 31).

The Ontario plain is much larger and lies between Lake Ontario and the Southwestern plateau, the southern boundary being marked by the "Helderberg escarpment." This large province slopes gradually to the shores of Lake Ontario and is remarkably free from relief features of any considerable magnitude. One that deserves mention is the presence of many hundreds of low, glacial knobs (drumlins) which are thickly scattered over the whole plain between Rochester and Syracuse (see plate 42). Another feature which serves to break the monotony of the plain on the west is the low but distinct escarpment of Niagara limestone, which extends from Lewiston eastward to beyond Lockport. On the east the Ontario plain gradually merges into the Mohawk valley province on the one hand, and on the other hand comes against the western foot of the highlands of the Tug Hill province.

The rocks underlying the Ontario plain are chiefly sandstones, limestones and shales of Siluric age, which show the usual tilt toward the south. At the extreme northeast, limestone and shale of Ordovicic age are present and these show a slight westward tilt.

TUG HILL PROVINCE

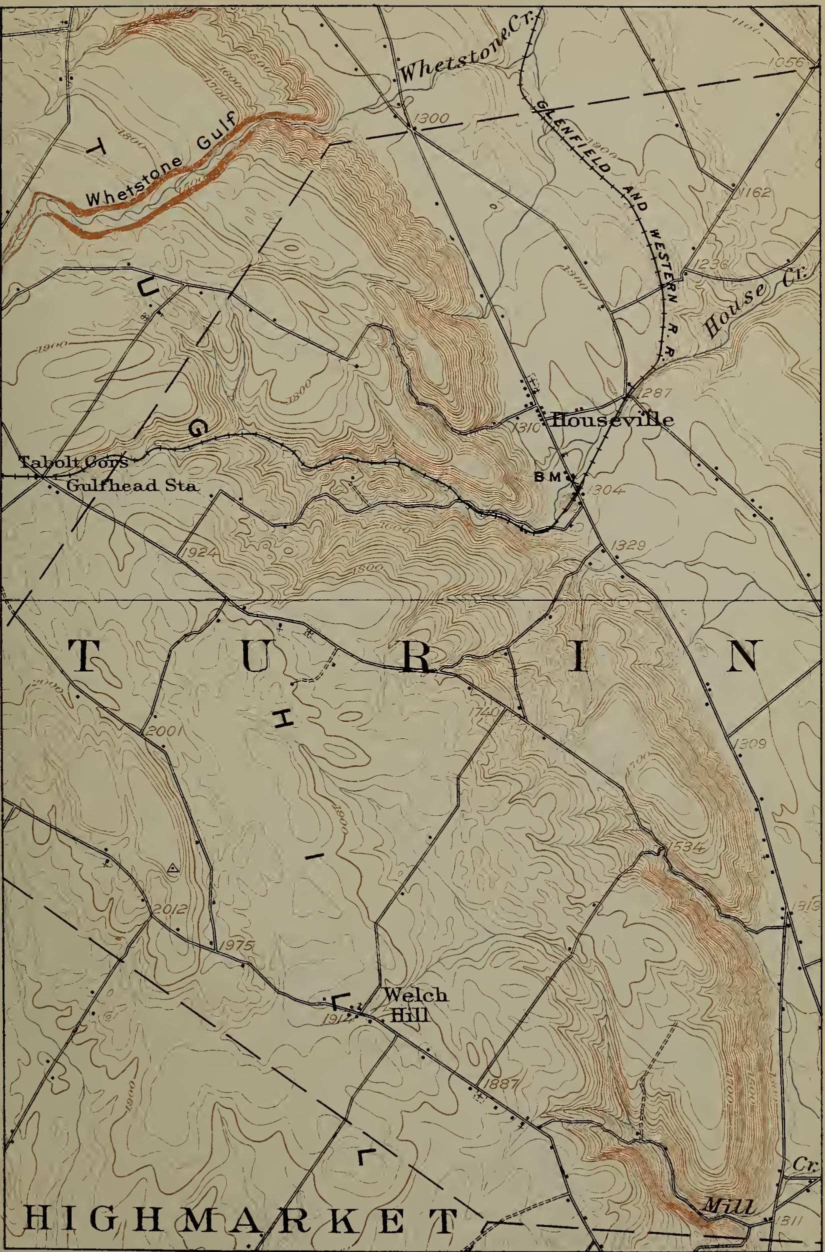
The Tug Hill region is worthy of recognition as a distinct physiographic province because we have here a highland mass of considerable extent entirely separated from the neighboring provinces. The highest point, six miles west-northwest of Lyons Falls, Lewis county, reaches an altitude of nearly 2100 feet, while the central portion of the province, covering many square miles, is remarkably flat and swampy with the general level above 1800 feet of elevation. On a smaller scale, this is as truly a plateau as the great Southwestern plateau already described and, interesting to note, this Tug Hill plateau is merely an erosion remnant of the great upraised Cretacic peneplain (see chapter 5) which formerly included all of New York State.

On the south and west this province slopes rapidly downward to the lowlands of the Mohawk valley and Ontario plain provinces, while on the east and north the Black river valley sharply separates this province from the Adirondack and St Lawrence Valley provinces. The rapid descent into the Black river valley bottom is everywhere 1000 feet or more over a series of high, steep terrace fronts (see plate 8). In passing, it should be stated that, though seldom recognized, this Black river depression takes rank as one of the few greatest valleys within the borders of the State.

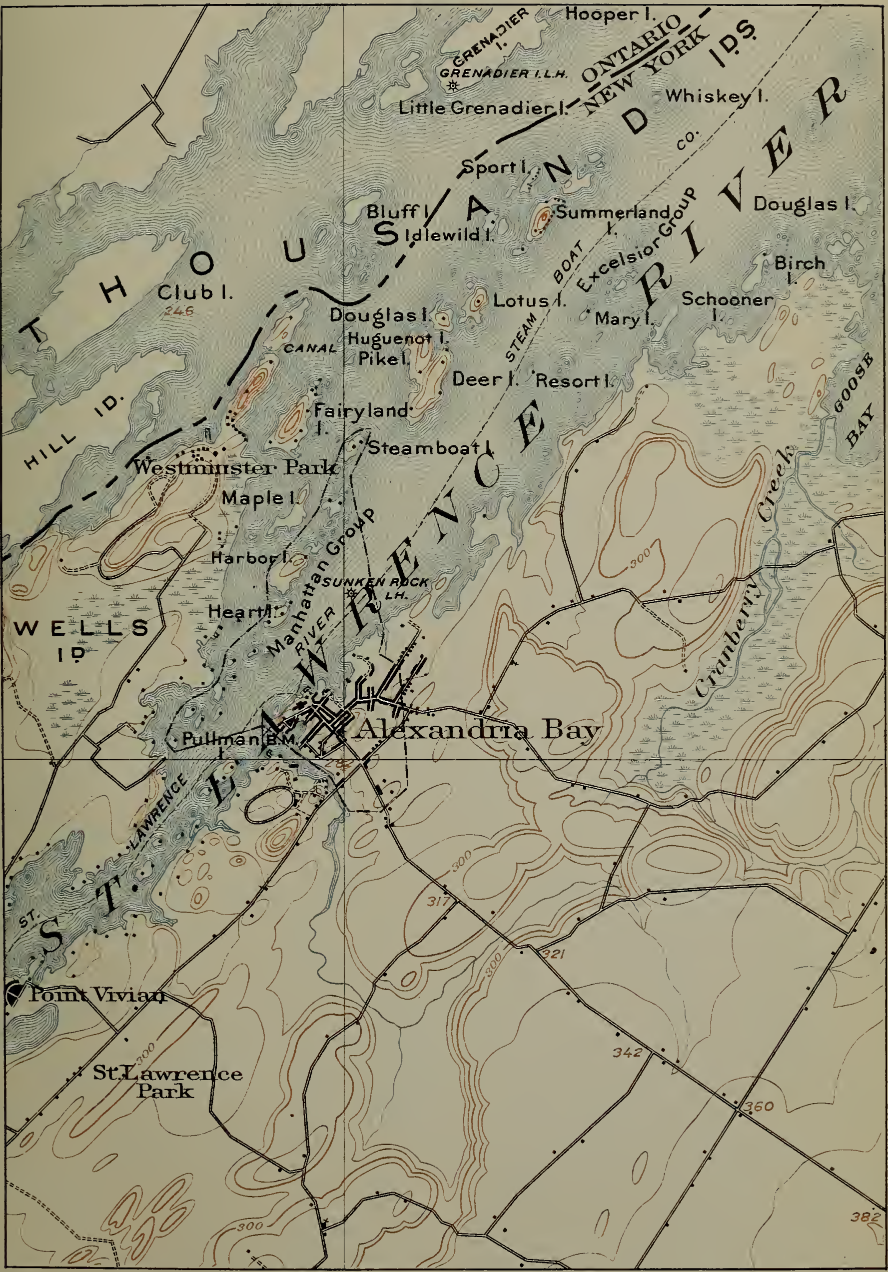
Near Boonville, and at an elevation of about 1100 feet, occurs the division of drainage between the Mohawk and Black rivers, and this divide forms the highest land connecting the Tug Hill and Adirondack provinces. But in spite of this partial connection and the close proximity of the province to the Adirondacks, the rock formations and structure are wholly different from those of the Adirondacks while they greatly resemble those of the Southwestern plateau. The rocks are all of lower Paleozoic (chiefly Ordovicic) age, with several hundred feet of limestone at the base followed by about a thousand feet of shales, the whole being capped by a resistant sandstone of Siluric age. These strata tilt slightly westward but they have never been disturbed by folding, faulting or igneous activity (see figure 35).

ST LAWRENCE VALLEY PROVINCE

The St Lawrence valley, lying along the northern boundary of the State, is a great, open depression of comparatively simple structure and near sea level. Where the river leaves Lake Ontario, the elevation is only 247 feet, while points with elevations more than a few hundred feet seldom occur within the province. As shown on the accompanying map (plate 9), low hills are common over the valley floor. The Thousand Islands form a remarkable physiographic feature of the province, where the wide, slow-moving St Lawrence river does not occupy any very distinct channel, but



A portion of the Port Leyden (U. S. G. S.) quadrangle, illustrating the topography of the Tug hill plateau. Note the high, general plateau level at from 1800 to 2000 feet above sea level and the abrupt termination of this plateau on the east side. Whetstone gulf is a fine example of numerous gorges cut through the steep plateau front. Scale, about 1 mile to the inch.



The Thousand Islands region in the vicinity of Alexandria Bay. The broad river, dotted with islands, does not here occupy a distinct stream channel in the usual sense of the term. A removal of the water would show that the topography of the river bottom is in no way essentially different from that of the country just south of Alexandria Bay. From Alexandria Bay (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

rather flows across a broad, low, hilly region of very moderate relief thus allowing the low rocky hills to stand out as islands.

The rocks are chiefly sandstones and limestones of Cambric and Ordovicic ages, though, in the vicinity of the Thousand Islands numerous patches of the underlying Precambric (Adirondack) rocks are exposed as on many of the islands themselves. Folds, faults and igneous rock are not present except in the Precambric rocks, and the strata may be regarded as a comparatively thin mantle of nearly horizontal layers overlying the Precambric rocks.

CHAMPLAIN VALLEY PROVINCE

The Champlain valley bounds the Adirondacks on the east and the province should be regarded as a great depression separating the Adirondacks on the west from the Green mountains on the east. Much of the valley bottom is filled by the waters of Lake Champlain (elevation 101 feet). Along the western shores of the lake the topography is characteristically hilly, though seldom above 500 feet in elevation. The transition to the higher and rugged Adirondacks is generally rapid.

The rocks occupying the valley bottom are sandstones, limestones and shales of Cambric and Ordovicic ages. These formations are much disturbed by numerous faults, often of considerable magnitude, and in fact there is good reason to think that the whole Champlain valley is of the nature of a great fault-trough or depression.

HUDSON VALLEY PROVINCE

General description. Looked upon in a broad way, the Hudson valley province is a depression lying between the western highlands of New England and the eastern highlands of New York. Well toward the south the true valley feature is somewhat interfered with by the presence of such elevated masses as Shawangunk mountain and the Highlands-of-the-Hudson. A very detailed classification of topographic features would call for four or five provinces instead of the one here called the Hudson valley province. Since even this southern part, however, is lowland compared with the Catskill mountains immediately westward and since the rock structures are so similar and characteristic throughout the region, though the kinds of rocks vary considerably, it seems best for our purpose to treat all together as the Hudson valley province and then very briefly describe each of the minor subdivisions of the province.

The foundation rocks of the whole province comprise various formations of Precambric, Cambric, and Ordovicic ages, while in a few places mere surface layers of Siluric, Devonic, and Mesozoic strata occur (see geologic map, figure 1). All the rocks, except these few younger surface layers, are highly folded, which constitutes the most characteristic structural feature of the whole province. In fact, as is hereafter shown (see chapter 4), there are here exposed the roots or remnants of a portion of the great and very ancient Taconic mountain range which at one time occupied this

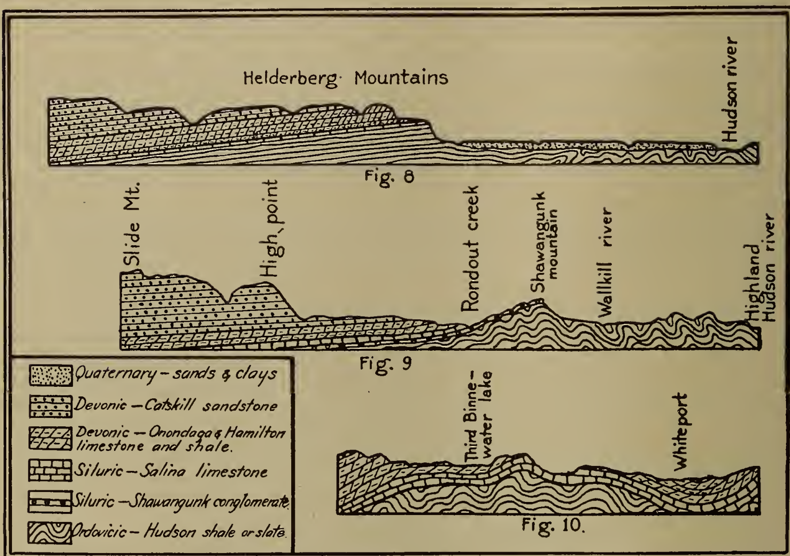


Fig. 8 Section from southwest to northeast through Albany county and showing the Taconic folds near the Hudson.

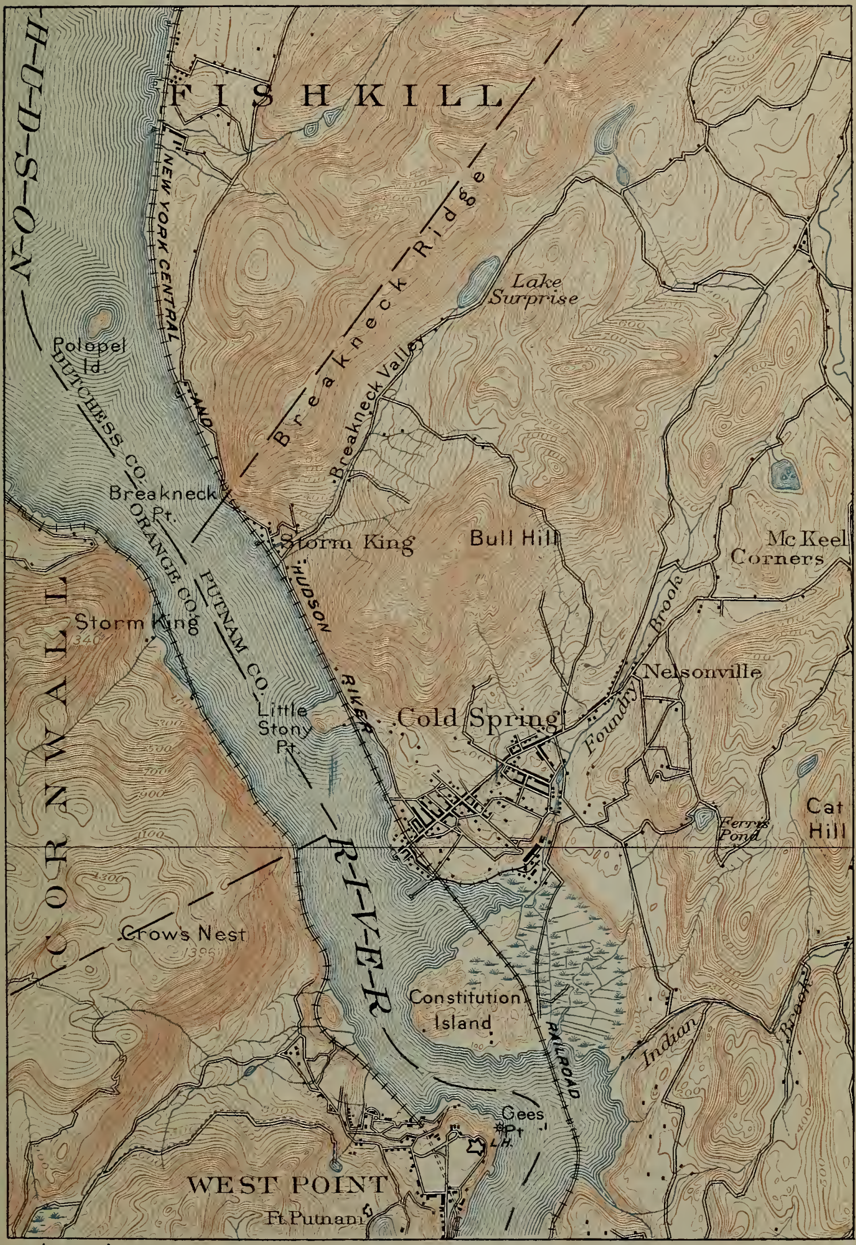
Fig. 9 Section from northwest to southeast across Ulster county and passing through Slide mountain and Highland village. Taconic and Appalachian folds both sides, as well as the structure of Shawangunk mountain.

Fig. 10 More detailed section through cement district at Whiteport, Ulster county. Both Taconic and Appalachian folds are well exhibited.

These sections all modified after Darton, N. Y. State Mus. Rep't 47, 1894, pp. 430, 490, 532

region. Thus from the geologic standpoint, the term Taconic province would be appropriate. All along the border of the province, as well as throughout the Hudson Highlands, the rocks are rather severely metamorphosed.

Highlands-of-the-Hudson. The Hudson Highlands extend across the Hudson valley in a northeast-southwest direction, and cover southern Orange county and northern Rockland county, and the region from southern Dutchess southward across Putnam



A portion of the West Point (U. S. G. S.) contour map, illustrating the topography of the Highlands of the Hudson. The river here flows through a deep, narrow gorge which has been cut through the northeast-southwest ridges of very hard Precambric rock. The sides of the gorge rise abruptly from the river to heights of 1200 or 1400 feet, while the rock bottom of the gorge is hundreds of feet below the river level. Scale, about 1 mile to the inch.

Looking north up the Hudson where the river flows through a deep narrow gorge in the hard granitic (Precambric) rocks of the Highlands. The mountain on the left is Crow's Nest and the nearer one on the right is Bull hill. Each of these mountains rises to more than 1400 feet above the river while the rock bottom of the river is buried some 600 to 800 feet. Compare with plate 20.

From N. Y. State Mus. Bul. 146 p.l. 16

and into Westchester county. The relief is rather rugged with the higher points commonly reaching altitudes of over 1000 feet. The rocks are chiefly granites and gneisses of Precambric age, and are in most ways much like those of the Adirondacks.

Region north of the Highlands. North of the Highlands the rocks are in the main highly metamorphosed shales, sandstones and limestones, and the relief is generally low except along the eastern border where it is almost mountainous. A characteristic feature along this eastern side is the presence of long, fairly high, nearly north-south ridges separated by comparatively narrow valleys.

Shawangunk mountain. Lying close to the southeastern border of the Catskills and extending northeastward from the State line in Orange county well into Ulster county, is a distinct mountain ridge known as Shawangunk mountain. This long, narrow mountain rises 1000 feet or more above the surrounding country, and with the deep narrow Rondout valley immediately on its west side and the broad, open Wallkill valley on the east, it is truly a remarkable topographic form. The capping of very hard Siluric conglomerate upon the soft Ordovicic shales has caused the ridge to stand out so boldly against erosion (see figure 9 and plate 28).

Region south of the Highlands. Southern Rockland county is covered by Mesozoic (Triassic) sandstone. This rock is not folded but contains within its mass great sheets of lava which outcrop to form the Palisades along and west of the Hudson (see figure 20).

In southern Westchester county and in New York county there are highly folded and metamorphosed Precambric and Ordovicic rocks, and the country is typically hilly.

LONG ISLAND PROVINCE

This province, including Staten Island, is really a part of the broad Atlantic coastal plain and is therefore practically devoid of any hard rock formations at the surface. Except for a few exposures of Cretacic sands and gravels along the northern border, the whole province is made up of glacial sands and gravels. From the standpoint of surface relief the province is clearly divisible into two parts, a northern and a southern, which are sharply separated from each other (see plate 12). The northern part is characteristically hilly, the hills being of glacial (morainic) origin. The maximum elevation is less than 400 feet, while in general the hills are from 100 to 200 feet high. This line of hills ends abruptly about midway of the island (north-south) and the southern part of the province is a sand plain of remarkable smoothness with a gentle slope toward the ocean.

DRAINAGE

Considered as a great watershed, New York State takes rank as one of the most noteworthy in the United States. The waters of the State, except for a little in the southeast, enter the sea at five widely separated places, namely, Gulf of St Lawrence, New York bay, Delaware bay, Chesapeake bay, and the Gulf of Mexico, through the five well-known rivers, namely, St Lawrence, Hudson, Delaware, Susquehanna, and Mississippi (through the Allegheny and Ohio rivers).

Mohawk-Hudson basin. The principal stream of this, the largest drainage basin of the State, is the Hudson river which is especially noteworthy in two ways, first because it is by far the largest stream whose course is wholly within the borders of the State, and second because soon after emerging from the Adirondacks (near Glens Falls), its course, for nearly 200 miles to its mouth, is remarkably straight in spite of the fact that it traverses the principal structural lines of a highly folded and disturbed region. Its apparently anomalous, deep, narrow, granite-walled channel across the Highlands of the Hudson (see plate 10) will be explained in chapter 6. The chief tributary and essential part of the Hudson, the Mohawk river, has its headwaters in the very center of the State and reaches the Hudson after flowing eastward for more than 100 miles.

The drainage of the southern Adirondacks, even as far north as Mount Marcy, and of the eastern Catskills passes into the Hudson river. Except for very minor contributions from the edge of New England and New Jersey, the whole river system derives its water from within the boundaries of the State.

St Lawrence basin. This drainage basin comprises all the northwestern Adirondacks and reaches well into the heart of the mountains. All the larger streams, which are of very moderate size, flow northwestward in remarkably parallel courses until, emerging upon the floor of the St Lawrence valley, they swing around to northeasterly courses and generally flow for a good many miles parallel to the great river itself before entering it. This latter phenomenon is, no doubt, to be explained on the basis of topographic changes due to the great Ice age. The largest and longest stream in the basin is the Raquette river which, after a devious course of more than 100 miles, including passage through two or three large lakes, enters the St Lawrence at the northern State boundary.

Ontario basin. All the streams of this basin enter Lake Ontario and pursue courses that, if continued, would tend to converge at a

A portion of the Islip (U. S. G. S.) quadrangle showing typical Long Island topography. Note the distinct hills (of glacial morainic origin) on the north, the perfect plain only very slightly stream-dissected and with very gentle seaward slope, and the long beach (built by wave action) inclosing the shallow bay with its many swampy islands. Scale, about 2 miles to the inch.

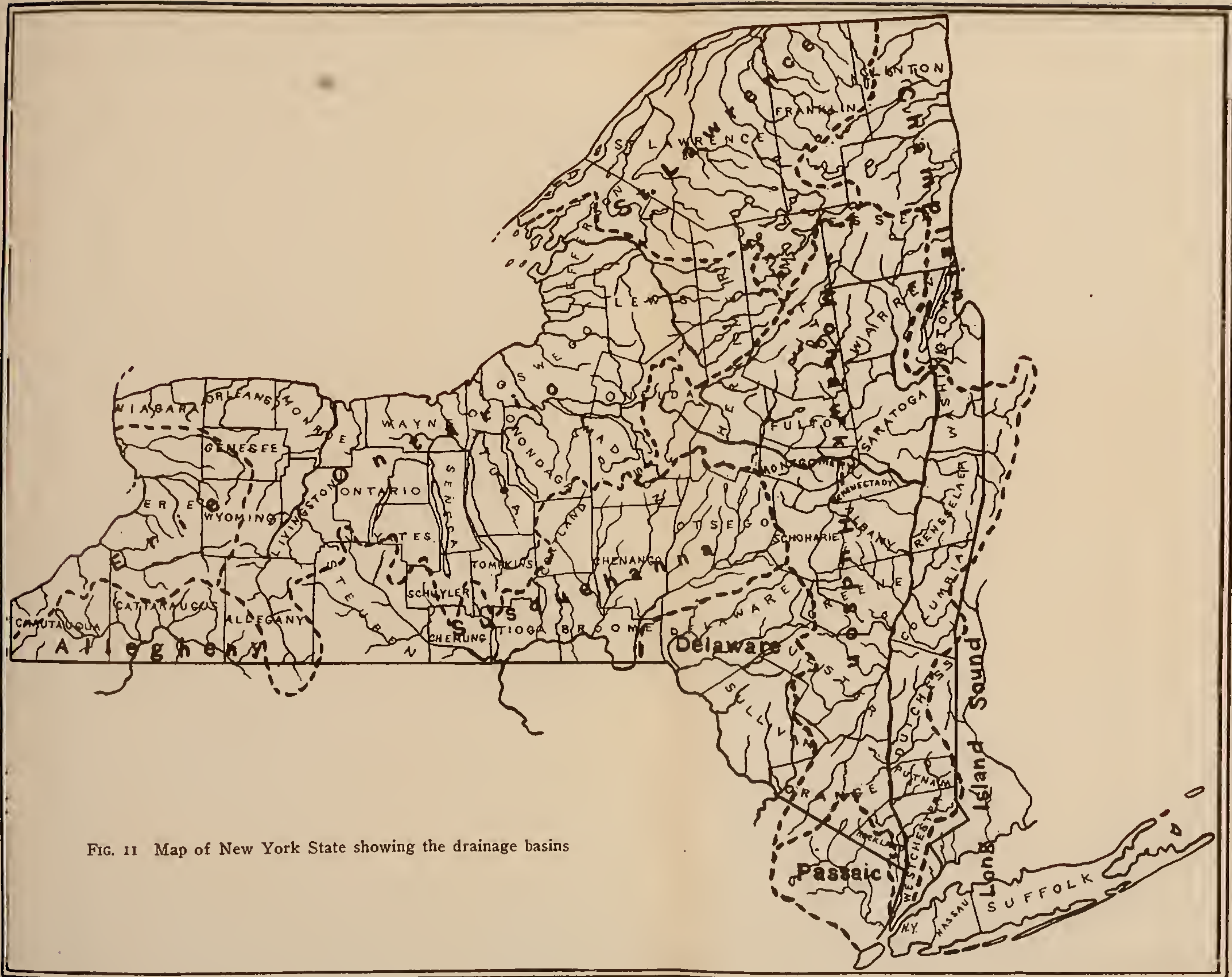


Fig. 11 Map of New York State showing the drainage basins

point in the lake basin. Thus the streams in the western portion of this drainage basin flow north to northeastward, northward in the middle portion, and westward to northwestward in the eastern portion. Three rivers should be mentioned: the Genesee, with its source in the highlands of Pennsylvania, flows northward across the entire southwestern plateau; the Oswego, toward the middle of the basin, takes one arm (Seneca river) from the west to drain the large Finger lakes and another arm from the east to drain Oneida lake and part of the Tug Hill plateau; Black river drains the extreme eastern portion of the basin, and a number of prominent tributaries flow southwestward from well within the Adirondacks to join the main stream in the great Black river valley.

Susquehanna basin. All the waters of the Susquehanna river are derived from the Southwestern plateau. The main stream (within New York) flows southwestward and together with its numerous large tributaries drains much of the eastern portion of the plateau region, especially in Otsego county. A number of the tributaries rise on the very crest of the Helderberg escarpment and within a few miles of the Mohawk river. The Mohawk river is fully a thousand feet below the crest of the escarpment, and its course is at right angles to that of Susquehanna tributaries.

The Chemung is the principal tributary from the northwest and drains a good portion of the south-central plateau.

Other drainage basins. The Champlain basin comprises the eastern border of the Adirondacks, including some of the highest and most rugged of those mountains. Nearly all the streams are short and most of them descend eastward very rapidly into Lake Champlain.

The Delaware, by means of its upper waters, drains the western and southern Catskills and the main stream, after flowing southeastward along the State line between New York and Pennsylvania, from Delaware county to Orange county, suddenly swings southwestward to pass through the famous Delaware water gap in the Kitatinny range.

The Allegheny river sends out a number of small branching arms to drain the extreme southwestern portion of the Southwestern plateau. Chautauqua lake (elevation 1338 feet) which lies at the very western edge of the plateau and close to Lake Erie, has its outlet into the Allegheny.

The Erie basin contains no river of much consequence, the small streams all flowing westward or northwestward across the narrow Erie plain and into Lake Erie or the Niagara river. Nearly all these streams rise along the western edge of the Southwestern plateau.

In quantity very little of the water of the State enters the Long Island sound basin, a few small streams north of the sound together with the numerous but very small streams of Long Island comprising the whole supply.

The Passaic basin is mostly confined to New Jersey, with a few small streams having sources in Rockland and Orange counties.

Chapter 3

PRECAMBRIC HISTORY

THE GRENVILLE FORMATION

In the Adirondack mountains, and also probably in the Highlands-of-the-Hudson, we have the earliest known records of the physical history of New York State. These records are written in a series of rocks named the Grenville, so called from a town in Canada where the rocks were first well known. The Grenville is of interest, not only because it is the most ancient rock formation so far discovered in New York, but also because it takes rank among the very oldest rock formations of the earth.

Until about fifteen or twenty years ago the real significance of the Grenville and its closely associated rocks in the Adirondacks was not recognized, but now many of the leading events of that very early history are established. As in human history, so in earth history, the earliest records are the most obscure and difficult to read and, in the one as in the other, it is easy to pass from conclusions properly based upon facts to mere speculations. Many problems regarding the Precambric history of our State yet remain to be solved, but in these pages it is rather the purpose to describe only those historical events which have been well established.

The Grenville consists of a great series of marine water-laid rocks which are clearly older than the Paleozoic because these latter rest upon the Grenville in many places. As will be shown below, the Grenville strata have been so profoundly changed from their original condition that certain of the highly sedimentary features have been obliterated. Thus the absence of water-worn particles and fossil shells, both of which are so characteristic of sedimentary deposits, is due to complete crystallization (metamorphism) of the Grenville strata since their formation. Nevertheless we have certain proofs of the sedimentary origin of the Grenville. The fact that these rocks commonly occur in alternating layers, which stand out in sharp contrast because of marked difference in composition and color, furnishes strong evidence that this distinct banded effect is due to differences in original sedimentation. A great mass of igneous rock is generally characterized by homogeneity throughout; a mass of typical sediments, on the other hand, is arranged in distinct layers, such as shale, sandstone, or limestone which show frequent differences in composition. In the Grenville, especially of the northwestern and southeastern Adirondacks, there are extensive beds of crystalline limestone, such as the Gouverneur marble of St Lawrence county. Such rocks could not have been of igneous origin. In many places, and sometimes in sharp contact with the limestone, are beds of almost pure quartz rock, which are certainly not igneous but which represent original sandstone layers. Again, there are very extensive deposits throughout the Adirondacks of generally darker colored rocks rich in such minerals as quartz, feldspar, garnet, mica, pyroxene, and amphibole. These rocks, because of their constant close association with the strata just described as well as their banded structure, are also clearly ancient sediments. The composition of these latter rocks shows that the original sediments were muds, often with sand or lime. Another argument in support of the sedimentary character of the Grenville is the presence of flakes of graphite (plumbago) which are so commonly disseminated throughout the formation. In some places the strata are so filled with graphite that the mineral is mined, as in Essex and Saratoga counties. Carbon existing under such conditions is probably of organic origin and represents the final stage in the decomposition of organisms which lived in the waters while the Grenville strata were being deposited. The occurrence of so much garnet is also at least highly suggestive because this mineral is especially common in crystallized sediments in many parts of the world.

Having established the sedimentary origin of the oldest known formation in New York State, we are led to the interesting and important conclusion that this Grenville formation is not the oldest which ever existed in the State. The Grenville sediments must have been deposited, layer upon layer, upon a surface of still older rocks. A knowledge of the character and composition of such Pregrenville rocks would be of very great interest, but thus far we have no positive evidence that such rocks are visible in the Adirondacks, although certain rocks still of somewhat doubtful age and origin may belong to that very ancient rock floor. Again, the fact that Grenville sediments were being deposited under water carries with it the corollary that there must have been land somewhere at no great distance from the area of deposition because then, as now, such sediments as muds and sands could have been derived only from the erosion or wearing away of land and have been deposited in great sheets one above the other, under water adjacent to the land mass. Here, too, we are as yet utterly in the dark so far as any knowledge of the location or character of that very ancient land is concerned.

Plate 13

An outcrop of typical Grenville (Precambric) limestone showing the folded or contorted and streaked character of the rock. View taken 1½ miles southeast of Johnsburg, Warren county.

W. J. Miller, photo

DISTRIBUTION, THICKNESS AND AGE OF THE GRENVILLE

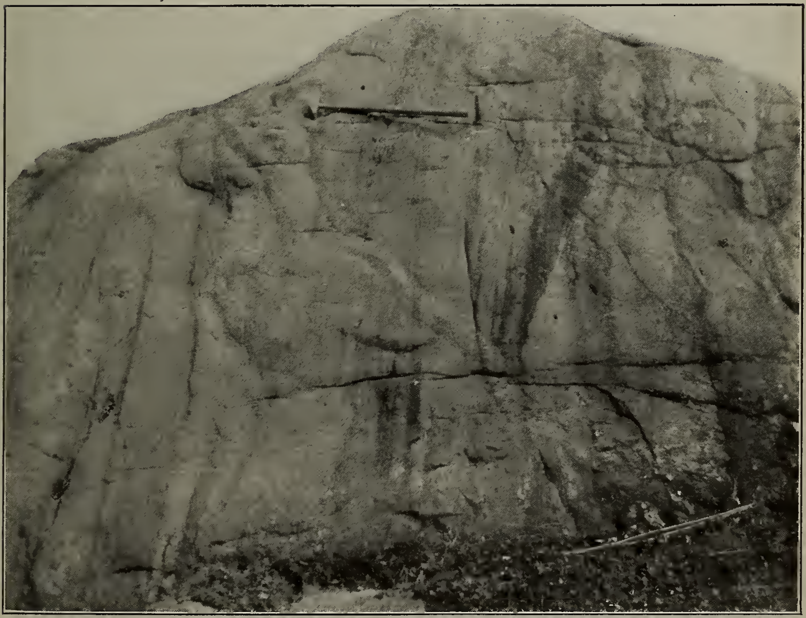
The Grenville is associated with rocks of younger age in the Adirondack region, so that the formation is not present as a single, continuous mass of surface rock covering the whole area. It is, however, so abundant and widespread in great and small areas throughout the Adirondack province that we may confidently assert that this whole district was under water during Grenville time. As the geologic structure strongly suggests and as certain deep wells prove, rocks of this age must extend, under cover of the later Paleozoic sediments, for a considerable distance beyond the Adirondack area. Precambric rocks have long been recognized in the Highlands district of the lower Hudson and recent work makes it practically certain that strata of Grenville age exist there. Precambric (doubtless including Grenville) occurs along the western border of New England and it should also be mentioned that Grenville strata are extensive over much of southeastern Canada. Presence of Grenville strata in southwestern New York is somewhat doubtful because, if there, they are effectually concealed under the heavy cover of Paleozoic strata. The positive existence of Grenville, however, just to the north in Canada and in northern and southeastern New York, makes it more than likely that the Grenville underlies the Paleozoic rocks of western New York also. Such a widespread distribution of the Grenville sediments shows that deposition went on in a very large body of water; large enough, in fact, to be called an ocean. *Thus, bearing in mind all the facts, we are led to the important conclusion that, during Grenville time, all of northern and eastern and probably southwestern New York was under the sea. In other words, the most ancient known geographic condition in New York was a great expanse of ocean water covering most, if not all, of the State.*

As the rocks are badly disturbed and folded, and as the top or bottom of the formation has never been recognized as such, it is impossible to give anything like an exact figure for the thickness of the Grenville rocks. Continuous successions of strata have been observed in enough places, however, to make it certain that Grenville strata were piled, one layer upon another, to a thickness of many thousands of feet. This clearly implies that the Grenville ocean existed for a vast length of time which must be measured by no less than a few million years, because in the light of all our knowledge regarding the rate of deposition of sediments, such a very long time was necessary for the accumulation of so thick a mass of rocks. It does not necessarily follow that the Grenville ocean was thousands of feet deep when the deposition began, because there may well have been a gradual subsidence of the sea floor during the process of sedimentation, which means that there was not necessarily very deep water at any time. In fact, the very character of the sediments clearly indicates that the Grenville ocean was, for most part at least, of shallow water, for such sediments as sands and muds have rarely if ever been carried far out into an ocean of deep water. The great ocean abysses of today are not receiving any appreciable amount of land-derived sediments. Hence it is practically certain that the very ancient Grenville sea bottom gradually settled as the sediments accumulated. Similar phenomena are definitely known to have occurred in many later basins of deposition.

The reader may naturally be disposed to ask, How long ago did the Grenville ocean exist? There are grave difficulties in the way of answering this question in terms of years, as we have nothing like an exact standard of this kind for comparison. While it is fully recognized that not even approximate figures can be given, a very conservative statement would ascribe an age of twenty to twenty-five million years to the Grenville strata. Whatever its exact duration may have been, the time is utterly inconceivable to us, and the important thing to bear in mind is that the great events of earth history which have transpired since that time require a lapse of many million years as shown by the enormous accumulations of sediments in many parts of the earth, and by the building up and wearing away of one great mountain range after another. The reader will better appreciate the significance of these statements after he has studied the following pages. In the table of geological time divisions given in chapter 1, the two oldest periods are the Archean and Algonkian respectively. The Grenville can not with certainty, as yet, be placed in either of these periods, although according to the best evidence it should be classed with the Archean. In the meantime it is advisable to refer to all formations older than the Paleozoic simply as Precambric.

LIFE IN THE GRENVILLE OCEAN

All that can be said regarding the life of the Grenville ocean is that it existed as indicated by the presence of the graphite. Although we can not even state whether the organisms were plant or animal, the fact that there was life in that very ancient ocean is a matter of no little significance. Anthracite coal, which is chemically



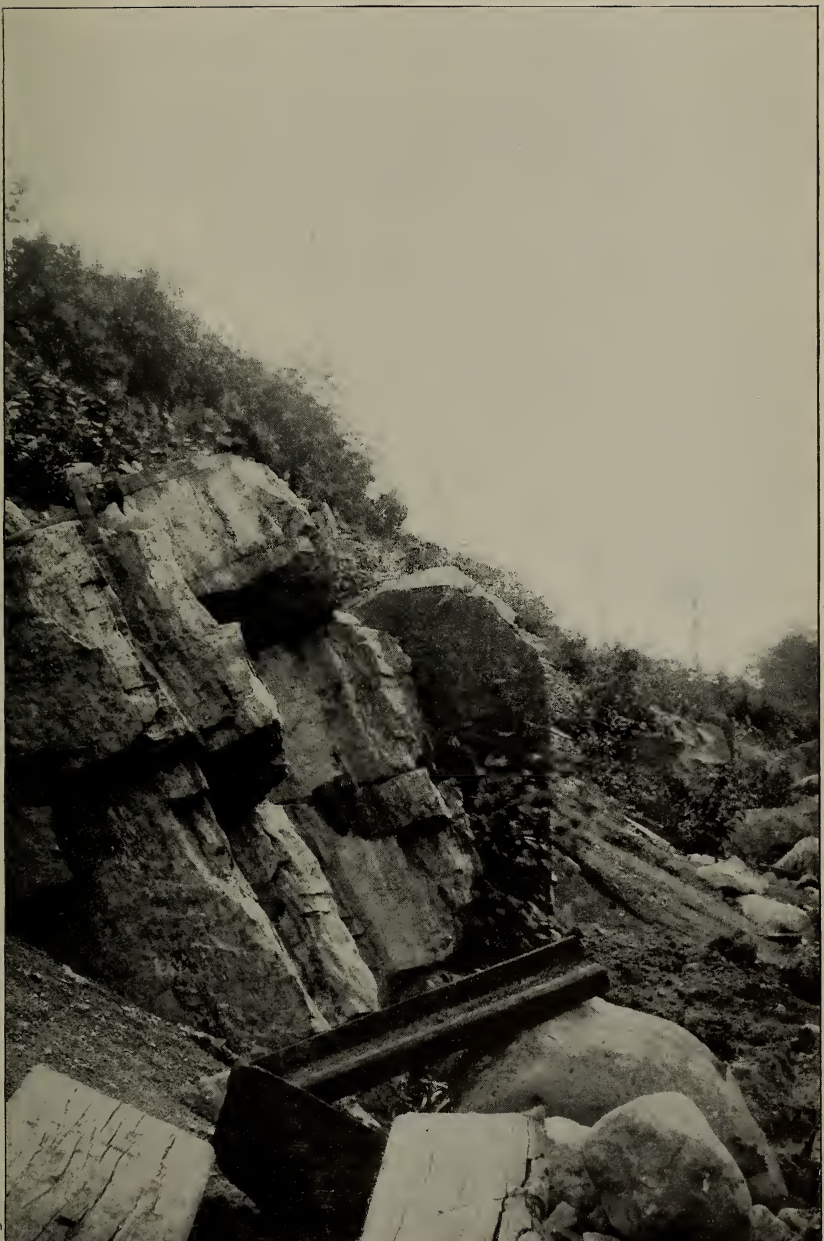
Upper figure. Typical outcrop of Adirondack Grenville gneiss, showing distinct stratification and tilted beds. Three-quarters of a mile north-northeast of Batchellerville, Saratoga county.

From N. Y. State Mus. Bul. 153, pl. 1

Lower figure. Typical outcrop of Adirondack syenite (igneous rock) at Harrisville, Lewis county.

From N. Y. State Geol. Rep't 1897, facing p. 470

Plate 15



A ledge of Precambric rock near Loon lake in the northern Adirondacks, showing the very ancient Grenville gneiss in sharp contact with syenite. The light and dark banded rock on the right is Grenville and the hammer is on the contact.

From N. Y. State Mus. Bul. 5, p .3

very similar to graphite, occurs in the Carbonic strata of Pennsylvania, and is derived from plants through the process of carbonization. Graphitic anthracite of like origin occurs in a smaller way in Rhode Island. Hence it seems likely that the graphite of the Grenville represents the remains of plants, probably of the seaweed type since there is much evidence against the view that any of the higher land plants existed at that very early time. This by no means proves the absence of animals from the Grenville ocean, because animals with only soft parts would have left no record, while calcareous or silicious shells would doubtless have been recrystallized by the severe processes of metamorphism to which these rocks have been subjected.

EARLY PRECAMBRIC IGNEOUS ACTIVITY

After the accumulation of the Grenville sediments, igneous activity, took place on a large scale, when great masses of molten rock were pushed or intruded into the sediments from below. Several different times of igneous activity have been definitely recognized and the general effect of the great invasions of molten rocks was to break the Grenville up into patches. In many cases considerable masses of Grenville were pushed aside or displaced by the molten masses while, to a greater or less extent, there may have been an actual melting in or assimilation of Grenville rocks by the molten intrusions. As we have already learned, igneous rocks are those which have cooled from a molten condition, and of these there are two important types, called respectively, plutonic and volcanic. Both of these types of igneous rocks are found in the Adirondacks, but the plutonics are by far the more prominently developed.

So far as we know, the first great intrusion of molten rock in the Adirondacks is represented by the present large area of so-called anorthosite in Essex and Franklin counties. This is a very coarse-grained, plutonic rock of bluish gray color when fresh and consists chiefly of a feldspar (labradorite). The intrusion was practically confined to a single area comprising about 1200 square miles. That this rock is younger than the Grenville is demonstrated by the fact that tongues of the anorthosite have been observed cutting through the Grenville (see figure 12). This intrusion differs from the later intrusions in that it was practically a single great mass which broke its way through the Grenville in but one place in the whole Adirondack region. In a few cases small patches of Grenville were caught in the molten flood and may now be seen within the anorthosite mass. For the most part, however, the molten rocks either completely pushed aside the Grenville or melted it into itself, the former being the more likely. Many of the highest points within the Adirondacks, like Mt Marcy, are in this anorthosite area.

The next clearly recorded event, after the anorthosite intrusion, was very widespread igneous activity when the rocks of the granite-syenite series, now so well known in the Adirondacks, were forced upward into the Grenville sediments. To be precise, there were at least two or three periods of intrusions of such rocks, the oldest probably being represented by the so-called Laurentian granite of the Thousand Islands region. For our purpose it will suffice to regard these as having all been intruded at about the same time, since the sum total of effects is much the same as though there had been but a single period of activity. Granite is a plutonic, igneous rock which consists essentially of quartz and feldspar (orthoclase),

FIG. 12 Generalized section showing the relations of the most common Precambric (Adirondack) rocks to each other and how their relative ages are determined.

together with more or less black mica, hornblende, or augite. Syenite is the same except that quartz is much less prominent or lacking. The fresh rock is of a greenish gray or pinkish gray color, while on weathered surfaces the color is usually light brown. Many of the highest mountains outside the anorthosite area are of granite or syenite.

The present distribution of these rocks shows that the molten masses broke into the Grenville in very irregular fashion, sometimes pushing the Grenville aside; sometimes enveloping great or small masses within the molten flood; or, in other cases, apparently leaving large Grenville masses intact. All portions of the Adirondacks felt the force of the intrusions and a detailed geologic map of the region would show a decided patchwork effect (see figure 13) due to the irregular manner in which the Grenville has been cut up by the igneous rocks. These igneous rocks are generally easily distinguished from the old sediments because of their homogeneity in large masses and lack of sharply defined bands of varying composition.

That these granite-syenite rocks are younger than the anorthosite is demonstrated by the fact that tongues of the former have been observed to cut the latter (see figure 12). Since the granite and syenite now visible in the Adirondacks are plutonic rocks, they

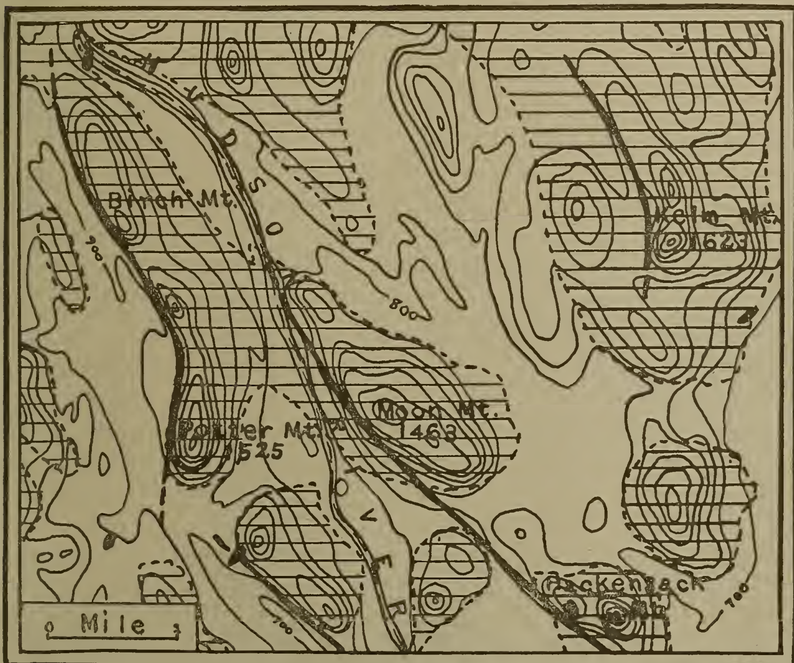


FIG. 13 Geologic and topographic sketch map of the southeastern portion of the North Creek sheet (Warren county), showing the surface relations of the common Precambric rocks in the southeastern Adirondacks. Contour interval 100 feet. Horizontally lined areas = syenite or granite; blank areas = chiefly Grenville; small heavy black lines are faults. The faults here shown are minor ones which do not follow the NE-SW trend of the major faults of the eastern Adirondacks. The so-called "patch-work" effect is well shown. Note how the more resistant rocks form the mountains which rise above the general level of the Grenville. (W. J. M.)

could not have reached the surface by intrusion, as such rocks can be formed only by slow cooling under great pressure thousands of feet below the earth's surface. They now appear at the surface because of vast removal, by erosion, of the overlying original materials.

It should be stated that this period of igneous activity is by no means confined to the Adirondacks. Similar intrusions are known in the Highlands-of-the-Hudson and in Canada. The covering of Paleozoic strata in southwestern New York prevents direct observation, but all things considered, it is more than likely that much or all of that part of the State, stripped of the Paleozoics, would also show Grenville cut up by granite and syenite.

FOLDING OF THE ROCKS AND UPLIFT OF THE ADIRONDACKS

At some time after these great periods of igneous activity and cooling of the rocks, the whole Adirondack region was subjected to an enormous pressure as a result of which the rocks were highly folded and compressed. The Grenville strata now seldom lie horizontally but are tilted at all sorts of angles, and even the igneous rocks thus far described, show unmistakable evidence of having been greatly compressed because the minerals are flattened out or arranged in parallel fashion, often exhibiting a crude, banded structure. Rocks which have thus been changed are known as gneisses and may be either igneous or sedimentary.

Still later than the granites and syenites, there occurred intrusions of gabbros in the form of dikes or fissures filled with igneous rock. This gabbro is a very dark gray, rather coarse-grained, plutonic rock, and it has been found in numerous small masses throughout the Adirondacks, but especially in the eastern portion. Its age, younger than the granite-syenite series, is demonstrated by the fact that it often breaks through those rocks, and also because it is not nearly so much metamorphosed.

The Grenville sediments were completely crystallized as a result of this metamorphism so that all beds of limestone were converted into marble, sandstone into quartzite, and the shales into gneisses of varying character. Thus the Grenville strata have been very greatly altered from their original condition, which explains why they do not look like the more typical and familiar sediments of later age. The manner in which the Grenville strata, especially the limestones, were crumbled and folded shows that the rocks must have been in a more or less plastic condition when the pressure was exerted (see plate 13). Heat and moisture, no doubt, aided in this process which we call metamorphism. Such a process can take place only at thousands of feet below the surface of the earth where the rocks, under the enormous weight of overlying material, would act like

Plate 16

View of Breakneck mountain where the Hudson river cuts across the Highlands. Seen from the shore opposite Cold Spring, Putnam county. The rock is Precambric granite. Back from the river, in these mountains, the character of the topography is much like that of the Adirondacks.

From N. Y. State Mus. Bul. 19, pl. 11

plastic masses when subjected to any great lateral pressure within the earth.[1]

Rocks at the surface of the earth, subjected to the same lateral pressure, would be broken or fractured instead of bent or folded. It is not the present purpose to discuss the origin of such pressure within the earth, but suffice it to say that it is somehow due to the shrinkage of the interior portion of the earth, and the tendency of the exterior (or crust) to accommodate itself to the shrinking interior, thus producing lateral thrust (pressure) in this exterior portion.

We are now ready to discuss the first known uplift of the whole Adirondack region above sea level, or what we may call the birth of the first known Adirondack mountains. As we have just learned, the very character and structure of the rocks now exposed in the region, show conclusively that they were at one time deeply buried under thousands of feet of overlying materials, and the inference is perfectly plain that those materials must have been removed by erosion. Extensive erosion of any land mass means that the land must be above sea level and thus we come to the important conclusion that *the great mass of Grenville sediments were upraised well above sea level.* Just when the great uplift occurred can not be positively stated, but if it was not during, or after the igneous intrusions, it must have been shortly before them. It is quite reasonable to believe that the same great force which caused a welling up of so much liquid rock might easily have caused a decided uplift of the whole region. Again, it is quite plausible that there may have been no great uplift until the development of the lateral pressure which caused the metamorphism of the rocks. Still another view is that a lateral pressure, once started, first caused a welling up, at different times, of igneous rock and then, after the cessation of the igneous activity, the same force continued to compress, fold and metamorphose the rocks. Whatever the actual history may have been, it is at least true that the sum total of all effects, as we now observe them, harmonizes well with the view last expressed. The intense folding and tilting of the strata show that the amount of uplift must have been very considerable as is the case in all typical mountain ranges. We can not, however, even state the approximate height of those very ancient Adirondack mountains. The fact

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[1] Professor Adams of McGill University, Montreal, has recently proved experimentally that rocks, under great pressure, flow like plastic matter.

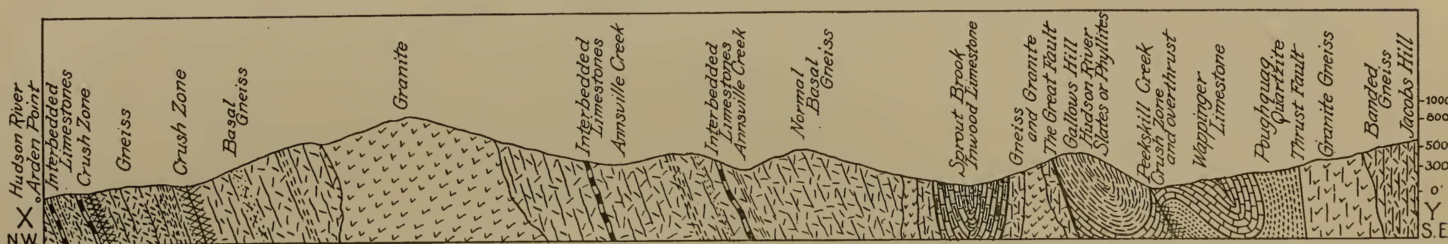


Fig. 14 Structure section through a portion of the Highlands-of-the-Hudson from a point on the river one mile south of Garrison and extending 6 miles southeasterly to Jacob's hill. The basal gneisses are highly metamorphosed and folded Precambric (Grenville?) sediments through which large masses of granite were erupted. Toward the right are closely infolded belts of early Paleozoic sediments.

After C. P. Berkey, N. Y. State Mus. Rep't 60, v. 2. 1907. p. 371

The upper view is of Potash mountain, locally called the "Potash Kettle," three miles north of Luzerne, Warren county. It is a remarkable feature of the landscape, the almost isolated mountain towering 1100 feet above the surrounding valleys. The rock is Precambric granite.

The lower view shows several dark lava (diabase) dikes cutting gray syenite three-fourths of a mile northwest of Northville, Fulton county. Both rocks are of Precambric age. Photos by W. J. Miller

that many thousands of feet of materials have been removed by erosion in order to expose the present rocks to view does not necessarily imply that the mountains at any time had so great a height because it is possible that, while elevation slowly progressed, material was steadily removed by the process of erosion. All our knowledge regarding later and better known mountains, however, leaves little doubt that those first Adirondacks were mountains vastly higher than those of today.

The same sort of uplift and succeeding profound erosion also affected the present region of the Hudson Highlands (see figure 14) and, this being the case, we can state with confidence that much, if not all, of northern and eastern New York was involved in this mountain-making process. For western New York the physical geography of this time has not been determined because all that region is so deeply buried under the Paleozoic strata.

LATE PRECAMBRIC HISTORY

The fact that such a great thickness of rock was removed by erosion implies a vast length of time for the accomplishment of that work. According to all that we know regarding the rates of erosion of mountains of the present and past, the erosion of the Adirondacks must have extended over a period of at least several million years. When we consider that, at the opening of Upper Cambric time, most of the region had been worn down to the condition of a peneplain (see page 42), we are confident that no small amount of the erosion was accomplished even before the opening of the Paleozoic era, and that it continued well into the early Paleozoic. The whole problem of this later erosion and its effects will be treated in the next chapter.

Well toward the end of Precambric time, igneous activity of a minor character took place in the formation of dikes which, as we have learned, are fissures in the crust of the earth which have been filled with molten rock. In the Adirondack region there are several kinds of dike rocks, the most common being pegmatite and diabase. Pegmatite is a very coarse-grained, light colored rock of general granitic composition, the feldspar and quartz crystals often attaining lengths of several inches to a foot. Diabase is a fine-grained rock much like ordinary basaltic lava. These dikes are generally less than a mile long and comparatively narrow. That they are younger than the other igneous rocks of the region is abundantly proved by the fact that they cut through those rocks in many places (see plate 17 and figure 12). That these dike rocks were intruded after the great pressure and uplift of the region is shown by the total absence of metamorphism or alteration of any kind along their contact lines. The fine-grained texture of these rocks, often with borders of glass, shows that they must have cooled close to the surface, and hence it is evident that most of the Precambric erosion of the region had been accomplished before the diabases were erupted. Such rocks suggest that there may have been volcanic activity at the surface but no positive proof for such activity can be given because, if such volcanic material ever existed, every trace of it has been removed by erosion. The diabases have been observed to cut the pegmatites and hence they are not only the younger of the two, but they must take rank as the youngest Precambric rocks in the State. In the Adirondacks the pegmatites are very widely distributed and common, while the diabases are most abundant in the northeast, less so in the northwest and southeast, and nearly absent from the southwest.

Chapter 4

PALEOZOIC HISTORY

CAMBRIC PERIOD

In the preceding chapter we have seen that after the first known great Adirondack uplift the whole region, including the district of the Highlands-of-the-Hudson, was profoundly affected by erosion, and that this erosion began before the Paleozoic age and extended well into the early part of that era. Now the question may be fairly asked, What became of the sediments which were derived from the wearing down of the land during that vast length of time? We must admit that, in our present state of knowledge, we can not be certain as to what became of the Prepaleozoic sediments. They may have washed westward or southwestward into waters which might possibly have existed there; or they may have been carried northward or northwestward into Canada to help build up late Precambric deposits there; or they may have moved eastward toward or into the Atlantic basin. The question of the disposition of the early Paleozoic sediments, however, can be much more satisfactorily answered. Early and Middle Cambric deposits are extensively developed in the New England states and along the eastern border of New York State, including the Hudson Highlands region. Thus we have positive proof for the presence of the early and Middle Cambric sea over this region, and it is equally evident that much of this sediment which deposited in the sea was derived from the adjacent land masses in northern and eastern New York.

It was not until the opening of the Upper Cambric (Potsdam time) that any considerable portion of New York State was occupied by Paleozoic sea water. The fact that all the Cambric strata, including Lower, Middle, and Upper, are present in the New England country and along the eastern border of New York, while only the Upper Cambric is present in northern New York, clearly shows that the Cambric sea encroached upon the State from the east toward the west. To be more exact, it was probably from the northeast, because the greatest thickness of Upper Cambric strata is in Clinton county along the northeastern side of the Adirondacks.

The first deposit to form in the Cambric sea of northern New York was the Potsdam sandstone and the presence of this formation in the St Lawrence, Champlain, and lower Mohawk valleys proves that the Potsdam sea occupied all these regions. Along the southwestern border of the Adirondacks the Potsdam is absent and there is not the slightest evidence that it ever was present, so that region must have been dry land in Potsdam time. In the southeastern Adirondacks the Potsdam sea certainly extended in as far as Wells (southern Hamilton county) and North River (northwestern Warren county), because small outlying masses of Potsdam sandstone occur at those places. These outlying masses were formerly connected with the larger areas but have become completely separated from them by extensive (Postpaleozoic) erosion and downfaulting. There is no evidence whatever that the sea covered the heart of the Adirondacks. *To summarize for northern New York, we may say that the Potsdam (Upper Cambric) sea covered the whole region except the central and southwestern Adirondacks which stood out as a great island in the midst of that ocean.* Southeastern New York certainly, and the middle eastern border of the State probably, were covered by the Upper Cambric sea, but whether that sea extended over the rest of the State has not been determined because all early Paleozoic strata, if present, are now deeply buried.

What do we know about the character of the topography of the land over which that ancient Potsdam sea spread? As a result of the very long erosion during late Precambric and early Paleozoic, thousands of feet of material had been removed so that rocks which had been so deeply buried were exposed at the surface, and the whole country must have been well worn down. Was the region worn down to the condition of a peneplain? Recent detailed studies on all sides of the Adirondacks furnish a very satisfactory answer to this question. In many places the Potsdam has been seen in actual contact with the Precambric rock whose surface oftentimes clearly proves that the whole region had reached a peneplain condition. Along the northeastern Adirondacks this peneplain was considerably rougher than along the northwestern and southwestern portions. This is explained by the fact that the northeastern area subsided first and consequently was not subject to wear quite so long as the latter named areas.

The accompanying figure (no. 15) affords an interesting example of the kind of peneplain topography here considered. It demonstrates that occasional low knobs of more resistant rock (for example, Grenville quartzite) protruded above the otherwise nearly featureless plain, because when the Potsdam sea overspread the

Plate 18

The Grand Flume of Ausable chasm, Clinton county. The rock is Potsdam sandstone in horizontal layers and the gorge is postglacial.

From N. Y. State Mus. Bul. 19, pl. 22

Plate 19

Potsdam (Upper Cambric) sandstone resting upon the eroded surface of Precambric rock (gneiss) at Corinth, Saratoga county. The difference in age of the two rock masses here in contact is millions of years.

From N. Y. State Mus. Bul. 19, pl. 20

region such low knobs were not covered by the water. At this same locality there is a fine exhibition of coarse conglomerate at the base of the Potsdam sandstone, the boulders of the conglomerate often ranging from one to three feet across. These boulders were torn off the Adirondack cliffs by the waves of the Potsdam sea and were deposited near shore in local depressions of the old rock surface. The sandstone itself everywhere abounds in ripple marks, thus proving the shallow water (near shore) origin of the rock. All the rock in the walls of the famous Ausable Chasm (Clinton county) is Potsdam sandstone (plate 18).

Immediately overlying the Potsdam and showing about the same areal distribution, are alternating sandstones and limestone beds (Theresa formation) which show a thickness of from 50 to 200 feet. After still greater subsidence, the important formation known as the Little Falls dolomite (limestone) was deposited, layer upon

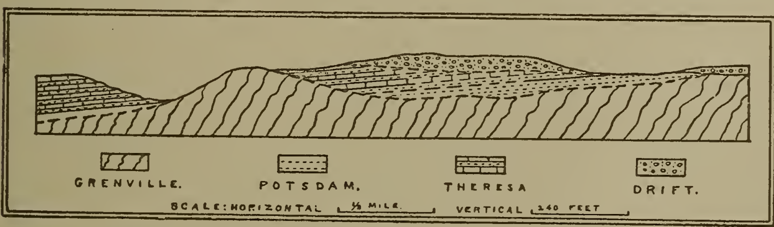


FIG. 15 Section passing through North Galway in Saratoga co. and showing how the Cambric (Potsdam and Theresa) strata overlap upon a hillock of Precambric rock. This knob of Precambric rock stood above the general level of the peneplain (early Paleozoic) and was not submerged under the Potsdam sea.

After W. J. Miller, N. Y. State Mus. Bul 153, p. 5

layer, in the Upper Cambric sea. This formation which is hard, compact and of light gray color, shows a thickness of several hundred feet in the gorge at Little Falls. It rests directly upon the Precambric rock there (see figure 7), which shows that the Cambric sea spread over that region for the first time when that dolomite was forming. The Little Falls sea swept all around the Adirondacks, except what is now the western border from Trenton Falls to the Thousand islands district. Occurrence of the dolomite in small outlying masses at Wells (Hamilton county) and Schroon Lake (Essex county) proves that the Little Falls sea extended well into the eastern Adirondacks. Rocks of this age appear to be present in southeastern New York and if so, the Little Falls sea also overspread that region. Direct evidence for western and southern

New York is wholly lacking, but judging by the occurrence in central Pennsylvania of rocks of the same age as the Little Falls dolomite, it is highly probable that the Little Falls sea also covered western and southern New York.

The Little Falls dolomite is especially significant in two ways; first, because it is the youngest (uppermost) Cambric formation in the State, and second, there is a distinct unconformity at its summit. By unconformity here we mean that, after the deposition of the dolomite, at least all of northern New York was raised (without folding or faulting) above sea level and underwent erosion for a moderate length of time after which most of the region again settled below sea level to receive the deposits of later (Ordovicic) age. This old eroded surface and unconformity has been well established, and hence we learn that *the great Cambric period of the early Paleozoic era closed with all of northern New York, at least, well above sea level.* In southeastern New York, so far as known, the Cambric strata appear to grade into the Ordovicic and if so, that region was not raised above sea level at the close of the Cambric. We are wholly ignorant as to the physical geography of western and southern New York at the close of the Cambric because the records there are not accessible, as they are deeply buried.

ORDOVICIC PERIOD

We are now ready to consider the physical condition of the State during the great Ordovicic period of earth history. During this time the Appalachian mountain region, the great Mississippi valley, and much of the far western region were almost continually under water (see figure 16). In fact, the very widespread distribution of thick Ordovicic strata shows that more of North America was covered by the Ordovicic sea than by any other sea, with the possible exception of the Precambric. Among the more prominent lands which persisted above water were Appalachia, a great land mass occupying what is now the Atlantic sea board and extending an unknown distance into the Atlantic, and another large land area in the Hudson Bay region of Canada. Sediments from those lands were washed into the Ordovicic sea which, for most part at least, covered the State during the entire period. In eastern and southeastern New York, the almost unbroken succession of Ordovicic strata shows that the sea was much of the time present there during the entire period. The prominent development of Ordovicic strata west and south of New York makes it practically certain

Plate 20

Little Falls (late Cambric) dolomitic limestone resting upon the eroded surface of Precambric rock as seen in a West Shore Railroad cut 1 mile west of Randall, Montgomery county.

From N. Y. State Mus. Bul. 19, pl. 25

that the western and southern portions of the State were submerged under the Ordovicic sea. In northern New York, however, there is no positive evidence whatever that the whole Adirondack area was ever completely submerged during this period. Accordingly the central Adirondacks formed a persistent island in the Ordovicic sea. Furthermore, in northern New York there were various rather

FIG. 16 Generalized map of North America showing the relations of land and water during the Midordovicic period. Horizontally lined areas = land; blank areas = water. All of New York State was submerged except the central Adirondacks which stood out as an island. The conditions in Mexico and Central America are practically unknown.

local oscillations of level bringing the land around the island now above and now below sea level, but all such details are here omitted. For our purpose it will suffice to say that, except for the Adirondack island, northern New York was mostly below sea level during the Ordovicic. To summarize the above statement: *New York State* *was completely submerged under the Ordovicic sea except for the Adirondack island and alternating land and water conditions immediately around that island.*

Without going into the details of the formations, it is important to note that the earlier Ordovicic deposits were almost wholly limestones, while the later deposits were nearly all shales and sandstones. Thus in southeastern New York the thick Wappinger limestone is overlain by the still thicker Hudson River shales and sandstones. In northern New York we have the Beekmantown, Chazy, Black River, and Trenton limestones overlain by the Trenton (Canajoharie), Utica, and Frankfort shales and sandstones. It should not be understood, however, that all the formations named are present in unbroken succession, because the oscillations of level (above mentioned) occasioned certain interruptions in sedimentation.

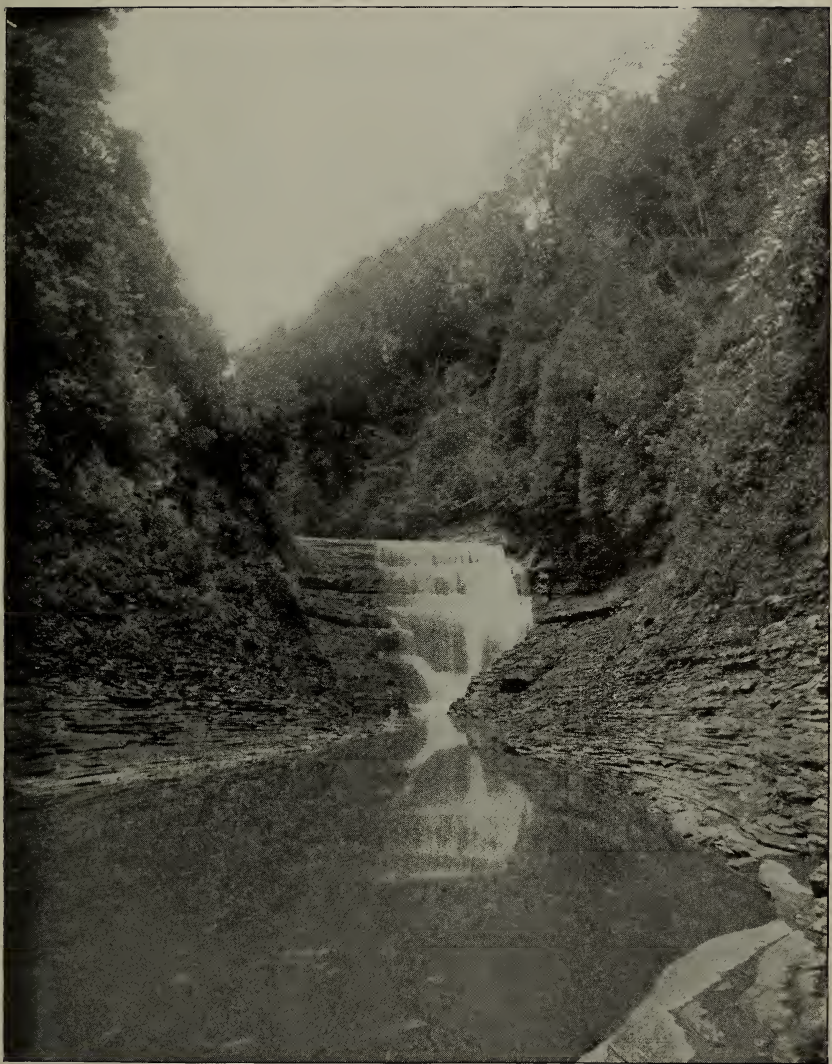
The predominance of limestone formation in the earlier Ordovicic sea of New York proves that the waters of that time were comparatively free from land-derived sediments and this, in turn, is best accounted for not by great depth of water and distance from land, but rather by the fact that all the nearest land areas were comparatively low and small, and hence were not undergoing very active erosion. During the later Ordovicic the adjacent lands were considerably higher and no doubt larger, so that vigorous erosion resulted and muds and sands were largely washed into the sea.

The aggregate thickness of Ordovicic strata in New York is between 2000 and 3000 feet. It should not be inferred from this fact that the Ordovicic sea was ever two or three thousand feet deep. Even the limestones abundantly show by ripple marks, mud cracks, fossils etc. that they were laid down in shallow sea water. The very character of the materials (old muds and sands) in the Upper Ordovicic formations shows that they could not have been deposited in deep ocean water. Such sediments are not now forming on the deep sea bottom. But how are these statements to be harmonized with the fact that nearly 3000 feet of Ordovicic strata exist in New York? During the whole period (with certain exceptions above noted) the land gradually subsided and in this slow downward movement stratum after stratum was formed upon the sinking sea-floor, so that at no time is it necessary to assume great depth of water. In general, the Ordovicic sea of North America must be thought of as a vast shallow (continental) sea which spread over most of the slowly subsiding continent. There were no ocean abysses at all comparable to those of the present ocean.

Trenton (Ordovicic) limestone at Sherman fall in the gorge at Trenton Falls, Oneida county. The thin-bedded and perfectly stratified character of this impure limestone is here well shown. This famous formation, loaded with fossils, was named from this locality.

From N. Y. State Mus. Bul. 95, pl. 9

Plate 22



Falls over Canajoharie (Trenton) black shale south of Canajoharie, Montgomery county.

From N. Y. State Mus. Bul. 19, pl. 35

In the strata of Cambric age in New York, animal or plant remains are comparatively rare, while the Ordovicic rocks throughout fairly teem with fossils. If any single formation deserves special mention, it is the Trenton limestone which is exceedingly rich in fossils. The type locality, at Trenton Falls, is justly famous as a collecting place for Ordovicic fossils. Among plants, none above very simple seaweeds or algae are known to have existed. Among animals, hundreds of species have been described as occurring in the Ordovicic strata of New York. These species represent all the more important subkingdoms and classes of animals below the vertebrates. Especially prominent are: corals, graptolites, star-fishes, brachiopods, gastropods and trilobites. All the organisms mentioned lived in the salt water, and if land life forms existed we know practically nothing about them. It must be borne in mind that not a single species of that time is known to live today, so complete have been the evolutionary changes since the Ordovicic age. Certain remarkable classes of animals like the graptolites and trilobites, which often fairly swarmed in the Ordovicic sea, have been wholly extinct for millions of years.

TACONIC MOUNTAIN REVOLUTION (CLOSE OF THE ORDOVICIC)

We are now ready to discuss the second well-known mountain-making epoch which affected New York State. We have learned that sedimentation along the middle eastern border and southeastern parts of the State was practically uninterrupted during all the Cambric and Ordovicic periods, and that some thousands of feet of strata had accumulated. At the same time extensive sedimentation was taking place in the seas which covered all the regions of the present Berkshire hills, Green and White mountains, as well as southward, at least as far as Virginia, over the region occupied by the present Piedmont plateau. *At or toward the close of the Ordovicic period a great compressive force in the earth's crust was brought to bear upon the mass of sediments which reached from north of New England to Virginia, or possibly farther southward. As a result of this compression the strata were tilted, highly folded, and elevated far above sea level into a magnificent mountain range known as the Taconic mountains.* In structure, the range consisted of a series of rock folds, both great and small, whose axes were parallel to the main axis of the range, that is north-northeast by south-southwest. Examination of figures 14 and 20 will give the reader a good conception of the character of the folding. It is quite the rule throughout this region of Taconic disturbance to find the strata either on edge or making high angles with the plane of the horizon. Many times the folds were actually overturned, and at times notable thrust faults or fractures[1] were developed, that is, the strata sometimes broke across and one great mass was pushed over another, as is well shown in many places in southeastern New York. These facts all go to indicate that the mountain-making compressive force applied to the region was of the extreme type, and though we have no way of telling just how high the range may have been, nevertheless the structural features and the vast amount of erosion since the folds were produced clearly indicate that the uplift was at least several thousand feet. The Green mountains, White mountains, Berkshire hills, Highlands-of-the-Hudson, and the Piedmont plateau are in a sense remnants of the great Taconic range.

In passing westward from the main axis of the Taconic range, the folding becomes less and less intense and finally dies out altogether. This fact is well illustrated by figures 6, 8 and 9. Along the Hudson river near Albany, the strata are fairly well folded, while a few miles westward the folds disappear. Passing eastward from Albany into Rensselaer county, one enters a region of excessive folding. In passing westward from Poughkeepsie, the intensity of the folding diminishes somewhat, but the shale formation is distinctly folded where it passes under the main mass of the Catskill mountains. Figure 6 clearly illustrates this fact.

How do we know that the Taconic disturbance occurred toward the close of the Ordovicic period? Another inspection of figure 6 will show that the strata of the next succeeding period (Siluric) rest directly upon the eroded edges of the folds of late Ordovicic rocks (see plate 25). Hence it is obvious that the disturbance occurred before the Siluric strata were deposited. What was the condition of the rest of the State just after the Taconic disturbance? In central New York, near Utica, a distinct eroded surface at the summit of the Ordovician shales proves that region to have been dry land toward the end of the period. On the north side of the Adirondacks and in the Champlain valley no formation younger than Ordovicic shale occurs, and all evidence points to uplift of that area into dry land toward the close of the period. Data are not obtainable for western New York. To summarize: *Practically all of northern-central, eastern, and southeastern New York (in-*

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[1] See figures 23 and 24 for explanation of faults.

Plate 23

A small fold in the Hudson river (Ordovicic) shales and sandstones along the lower part of Catskill creek in Greene county. This fold was produced at the time of the Taconic revolution.

From N. Y. State Mus. Bull. 19, p. 36

cluding the great Taconic mountains) was dry land toward the close of the Ordovicic period, while the physical geography of western New York for that time is not certainly known.

It should be noted in passing that the rocks of the Highlands-of-the-Hudson were, for a second time, clearly involved in mountain-making disturbances. The structural features of the Taconic mountains are finely exhibited in southeastern New York from Poughkeepsie to New York City, where one literally passes across the roots of the former great range. The distinct northeast-southwest trend of the topographic relief in this part of the State is due to the fact that the relief is still largely controlled by the Taconic folds and faults. The Hudson river has cut a deep channel across these structure lines, and along its banks excellent opportunity is afforded for the study of the rocks, folds, faults etc.

Another feature which must not be overlooked is the profound metamorphism of the strata along the main axis of the range. The very intense compression, under very high moist heat, caused the deeply buried strata along the main axis of uplift to become rather plastic, and hence the sediments became more or less foliated and crystallized into the various metamorphic rock types, the limestone becoming marble, the shale becoming slate or schist, and the sandstone becoming quartzite. Thus we have extensive marble quarries in southern Vermont, the slate in the quarries of Washington county, New York, and the Berkshire schist in the Berkshire hills of Massachusetts. In passing down the Hudson river from Kingston to New York City, the several stages in the metamorphism of the Ordovicic slate formation are finely illustrated. Thus, from Kingston to near Poughkeepsie the strata are distinctly folded but not metamorphosed; from Poughkeepsie to the Highlands, the strata are highly folded and partially metamorphosed, the shale layers nearly always having been changed to slate, while the associated and more resistant sandstone layers have escaped change; from the Highlands to New York City the rocks have been highly folded and metamorphosed, both shale and sandstone having been converted into schist locally called the Manhattan schist. For example, the rocks exposed in Central Park are Manhattan schists which are believed to have been originally Hudson River shales and sandstones which have become thoroughly crystallized by intense metamorphism.[1]

[1] Professor Berkey has recently suggested the possibility that the Manhattan schist may be Precambric in age; if so, the latter part of this statement does not apply.

Accompanying the Taconic disturbance and possibly aiding the metamorphism were minor molten rock intrusions in the form of dikes. These dikes break through late Ordovicic strata and hence can not be older than late Ordovicic. A fine example of one of these dikes on Manhattan island is shown in plate 24.

The great compressive force which folded and upraised the Taconic mountains did not accomplish its work suddenly. The force was slowly and irresistibly applied and the mass of strata was gradually bulged and bent, or fractured if near the surface, the amount of time required for the whole operation being perhaps very long but beyond estimate. Such a length of time is, however, so short compared with all known geologic history that we are accustomed to refer to the formation of such a mountain range as simply an event of earth history.

From these statements we see that, even before the range had attained its maximum height above sea level, a very considerable amount of erosion must have taken place. When the very first fold appeared above the ocean level, erosion began its work and continued with increasing vigor as the mountain masses got higher and higher. Thus we have the warfare between two great natural processes — the building up and the tearing down. So long as the building up process predominated, the mountain range increased in elevation, and we say the range was in its period of youth. When the opposing forces were about equally balanced, the range tended to remain at a constant elevation and we say the mountains were in the period of maturity. When the tearing down (erosive) process was predominant, we speak of the range as having been in old age. When the mountains have been completely worn down close to sea level (peneplain) we speak of the death of the range.

Here is an example of one of the remarkable procedures of nature. After millions of years of work by the deposition of thousands of feet of strata, layer upon layer on an ocean bottom, a great compressive force is brought to bear and a magnificent mountain range is literally born out of the ocean. No sooner is this great mountain range well formed than the destructive processes unceasingly destroy this marvelous work. But the sediments derived from the wear of this range are carried into the nearest ocean again to accumulate and after long ages to be raised up into another range; and so the process is often repeated. From this we learn that the mountain ranges of the earth are by no means all of the same age. The Adirondacks are older than the Taconics, and these older than the Appalachians; the latter, in turn,

Granite dike in Hudson River or Manhattan schist, as seen on the south side of 192d street, New York City. The schist is metamorphosed Hudson River (Ordovicic) shale and sandstone and the granite, while molten, broke its way through. The steep tilt of the schist layers was produced by the Taconic disturbance.

From N. Y. State Mus. Bul. 19, pl. 1

being older than the Sierras and the Coast ranges. Much of the material making up the mass of the Catskill mountains was derived from the wear of the Taconic mountains, deposited in the sea just to their west and later raised high above sea level.

SILURIC PERIOD

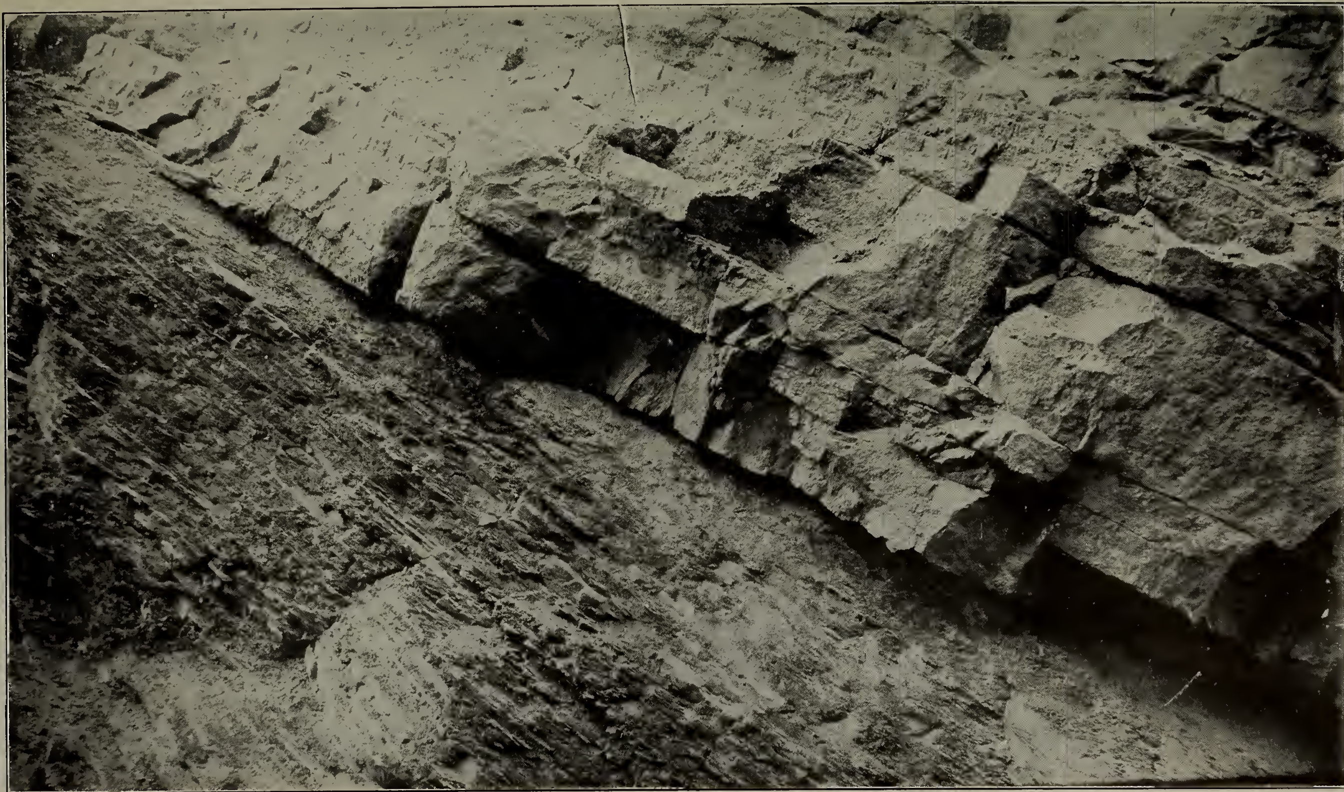
The close of the Ordovicic age or the opening of the Siluric found practically all the State above sea level and undergoing erosion. Along the eastern side the great Taconic range stood out prominently, but over the rest of the State we have no evidence that the land was very high. The central portion of the Adirondack region probably stood out somewhat more prominently than the western region.

As shown on the geologic map (figure 1), the Siluric strata outcrops in a comparatively narrow belt which runs along the western side of the Hudson valley to the Helderberg hills, southwest of Albany, where it swings sharply around westward to follow the south side of the Mohawk valley, and thence as a somewhat wider belt along the south side of Lake Ontario. These Siluric strata everywhere dip under the Devonic (surface) rocks of the Catskill and Southwestern plateau provinces. This fact, combined with the knowledge that the strata are largely of widespread marine origin and also outcrop abundantly in central Pennsylvania, makes it practically certain that the Siluric rocks underlie all of the Catskill and southwestern plateau regions. *Thus we must conclude that at least during much of Siluric time all of New York State south of Lake Ontario and the Mohawk valley and west of the Hudson river, was covered by sea water.* That the earliest Siluric sea did not spread over the area is proved by the absence of the very earliest known Siluric deposits. Furthermore, we know that the sea transgressed upon the State from the south or west, the Taconic range forming an effective barrier on the east and total absence of Siluric strata in the St Lawrence and Champlain valleys (as well as in Canada just north of the State) precluding encroachment of the sea from the north.

This encroachment of the sea over so much of the State was due to a gradual sinking of the land. That central and western New York was submerged before the Hudson valley region is proved as follows: In central New York (south of Utica) the first deposit to form upon the eroded surface of the Ordovicic shales was the Oneida conglomerate which passes westward into the Medina sandstone. In southeastern New York (for example, the Shawangunk mountain) the first Siluric deposit to be laid down upon the eroded Ordovicic shales was the Shawangunk conglomerate. This latter formation, as determined by its fossils, belongs with the Salina division and is therefore much younger than the Oneida conglomerate which belongs with the Medina division (see table in chapter 1). Also the whole of the Clinton and Niagara formations, which are so well developed in central and western New York, were never formed in eastern or southeastern New York. Thus the Siluric sea, due to subsidence of the land, overspread central and western New York long before it reached the Hudson valley region. In fact it was not until late in the period that the sea encroached upon the Hudson valley area, and then it did not occupy all that area because the shore of the Siluric sea extended only as far east as the western slope of the Taconics. Western New York, during the late Siluric, was a more or less cut off basin or arm of the sea in which the salt beds were deposited.

How much, if any, of the Adirondack region was covered by the Siluric sea? The total absence of any formation later than the Ordovicic shales around the northern Adirondacks and across the line in Canada strongly suggests that this region was upraised toward the close of the Ordovicic period, perhaps at the same time as the Taconic revolution, and continued as dry land not only during the Siluric but also during all the ages up to the present, except for a very brief local submergence during the Quaternary (see figure 34). In the southern Adirondack area the case is somewhat different. The outcrops of Siluric strata beneath the steep front of the Devonic Helderberg escarpment immediately south of the Adirondacks, makes it certain that these strata and the Siluric sea formerly extended farther north. The difficulty comes in trying to decide how far northward these rocks once extended, because there is now not a single scrap of Siluric rocks north of the Mohawk river, though the cap rock (Oswego sandstone) of the Tug Hill plateau is probably of Siluric age. All we can say is that the Silurian sea probably overspread the southern border of the Adirondacks and that the sediments which were deposited there have since been removed by erosion. To summarize: *During the early Siluric the sea had spread over only central and western New York, while during the late Siluric it had extended over practically all the State west and south of the Adirondack region.*

The strata of Siluric age were deposited sheet upon sheet in the usual manner upon the sea bottom. For our purpose we may con-



Shawangunk (Siluric) conglomerate resting upon the eroded edges of Hudson River (Ordovicic) shales, thus showing a sharp contact between rocks of two great periods of earth history. The shale layers are more steeply inclined because they were affected by both the Taconic and Appalachian disturbances, while the conglomerate was affected only by the latter disturbance.

From N. Y. State Mus. Rep't 60 (2), 1906, pl. A, facing p. 298

sider that sedimentation was uninterrupted, though as a matter of fact there were certainly minor oscillations of level which inter-

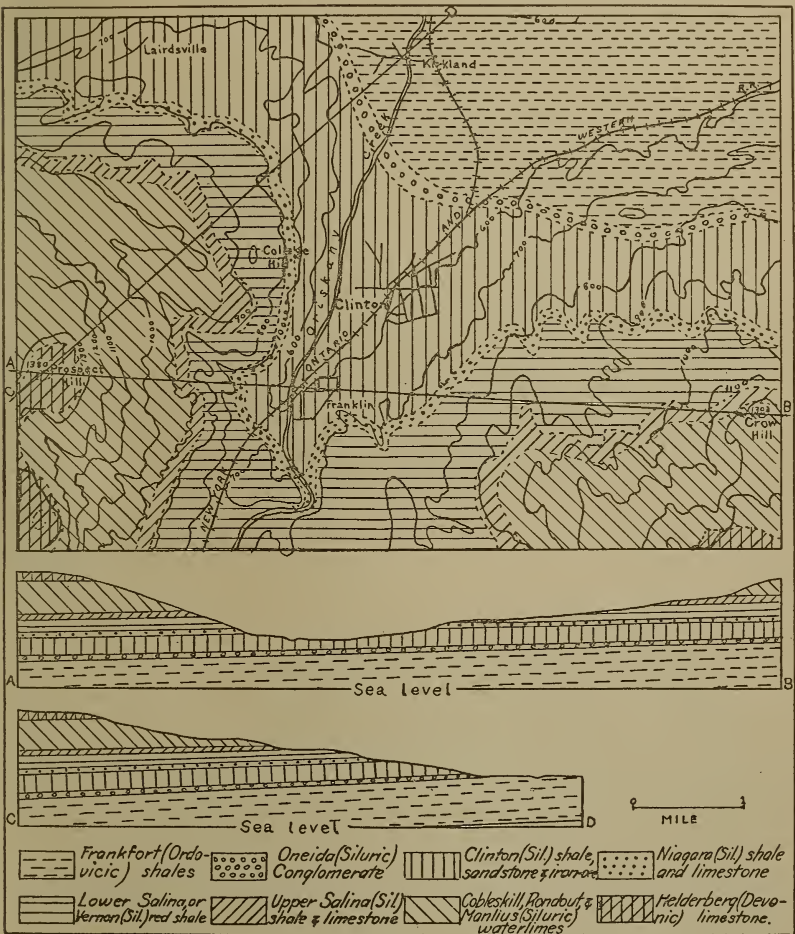


FIG. 17 Geologic and topographic map and structure sections of the vicinity of Clinton (Oneida county) showing the surface distribution and underground relations of the various rock formations from the Upper Ordovicic to the Lower Devonic inclusive. Note the simple nonfolded and nonfaulted structure, and the gentle southwesterly dip (tilt) of the formations. A similar simple structure characterizes the formations of the whole southwestern plateau province. Vertical scale of the sections four times exaggerated.

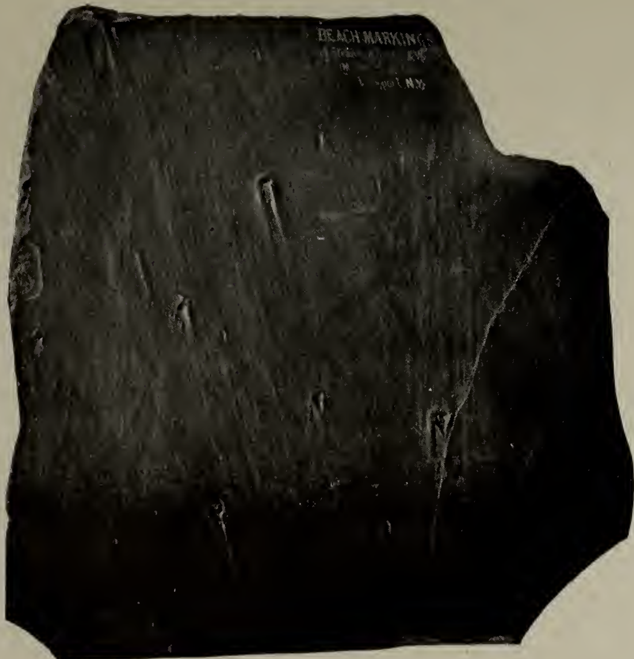
Geology by W. J. Miller

fered with the deposition of sediments and produced slight unconformities. These minor interruptions have not yet been carefully studied and hence need not be considered here. The total thickness of Siluric strata along the line of outcrop in the State varies considerably. In central and western New York the thickness is generally from 1000 to 1500 feet, while in southeastern New York it is much less since only the thinned upper formations are present.

The first Siluric sediments to form in central and western New York are called the Oneida conglomerate and Medina sandstone, these two being of practically the same age. These coarse deposits were washed into the shallow sea from the northern lands, that is in Canada and the Adirondack region. Next in order came the deposits of Clinton age, which consist of layers of shale, sandstone and iron ore. Above the Clinton come the Lockport and Guelph formations made up of shales and dolomitic limestone, the limestone forming the crest of Niagara Falls. None of the formations, so far mentioned, extend to the Hudson valley, but with the opening of the great Salina epoch Siluric deposits for the first time reached to the Hudson valley region where the earliest rock to form was the Shawangunk conglomerate which rests upon the eroded Ordovicic shales at the summit of Shawangunk mountain. This rock is entirely confined to southeastern New York, while rocks of the same age in central and western New York are shales and limestones. In this latter region the lowermost (oldest) Salina formation is the Vernon red shale, usually from 100 to 300 feet thick, which, in the western part of the State, is overlain by the salt and gypsum beds. Deep wells have proved the presence of the salt beds under practically all the Southwestern plateau. The salt was deposited in great salt lagoons and the climate of the time must have been arid. With an influx of fresh water into the lagoons, the type of deposit changed, and the hydraulic limestone (water lime) beds were formed all the way across the State to the Hudson valley region. These water lime beds are quarried at many places along the line of outcrop across the State, but more especially in the famous Rosendale cement region (see plate 33). Next in order, and marking the summit of the Siluric, come the Cobleskill, Rondout, and Manlius limestones which, though not very thick, are remarkably persistent across the State.

As to the life of the Siluric seas it may be said that it is in effect the continued existence of the same organic groups that preceded in the waters of Ordovicic time, though some diminished, some increased and some new ones made their first appearance. Thus the graptolites and trilobites greatly diminished, while the echinoderms (star fishes) increased, and the brachiopods and mollusks held

Plate 26



Beach markings on Medina sandstone

Seaweed, Arthrophycus harlani, on Medina sandstone
From N. Y. State Mus. Bul. 19, pl. 45

Plate 27

Niagara river gorge below the Suspension bridge, as viewed from the Canadian side. Very distinctly stratified beds of lower Siluric (Medina, Clinton and Niagara) age are shown.

From N. Y. State Mus. Bul. 19, pl. 55

Plate 28

The eastern face of Shawangunk mountain, 2 miles south of Lake Mohonk, Ulster county. The light colored rock forming the summit of the ridge is the very resistant Shawangunk conglomerate which protects the soft underlying mass of Hudson River (Ordovicic) shales.

From N. Y. State Mus. Bul. 19, pl. 40

Plate 29

Awosting falls over Shawangunk conglomerate, Peterkill, near Lake Minnewaska, Ulster county

From N. Y. State Mus. Bul. 19, pl. 42

their own. Fossil seaweeds, but not animal remains, are common in the Oneida-Medina beds. Various fossils exist in profusion in the Clinton and Niagara formations, while in the middle Salina beds fossils are altogether absent because the water of that time was intensely saline. The waterlime beds at the base and top of the Salina are usually poor in fossils except for the remarkable assemblage of organic remains known as eurypterids which belonged to the arachnid class but are now wholly extinct. Fossils are generally rather common in the uppermost Siluric beds of the State.

DEVONIC AND CARBONIC PERIODS

The Devonic history of New York State is comparatively simple and the records are remarkably well shown in rocks of that age. *Devonic strata comprise the whole Catskill and Southwestern plateau provinces, except for a few small patches of Carbonic rocks, and thus cover more than one-third of the area of the State. They are more widespread on the surface than the rocks of any other age.* The combined thickness of the Devonic strata is over 4000 feet, which is considerably more than for any other Paleozoic period in the State.

That the Devonic strata, on the Hudson valley side, formerly extended some miles farther eastward than they now do is proved by the presence of small outliers of Devonic rock, for example, Becraft mountain just southeast of Hudson, the Rensselaer grit farther north and the Skunnemunk mountain southwest of Newburgh. During part of the time the Devonic sea, or arms of it, reached as far east as these outlying masses and doubtless far beyond over the regions of Massachusetts and the Connecticut valley. The bold outcropping edges of thick Devonic strata facing the Mohawk valley and, in the Helderberg escarpment, the Ontario plain, make it certain that the strata formerly extended some distance farther northward. It is more than likely that this northward extension of Devonic rocks was not beyond the southern border of the Adirondacks; at least we have no positive knowledge that the Devonic sea ever covered any of northern New York (see figure 18).

There was no disturbance of any kind at the close of the Siluric, so that period passed very quietly into the Devonic. The Oriskany sandstone was for many years regarded as the base of the Devonic but now, as a result of a careful study of the fossils, the line between Siluric and Devonic is drawn just below the Helderberg limestone. As is the case with the Siluric, the rock formations are piled one upon another like great sheets and all show a gentle southward dip (see figures 3 and 5). Beginning at the bottom, the Helderberg limestone was succeeded in regular order by the Oriskany sandstone, Onondaga limestone, Marcellus and Hamilton

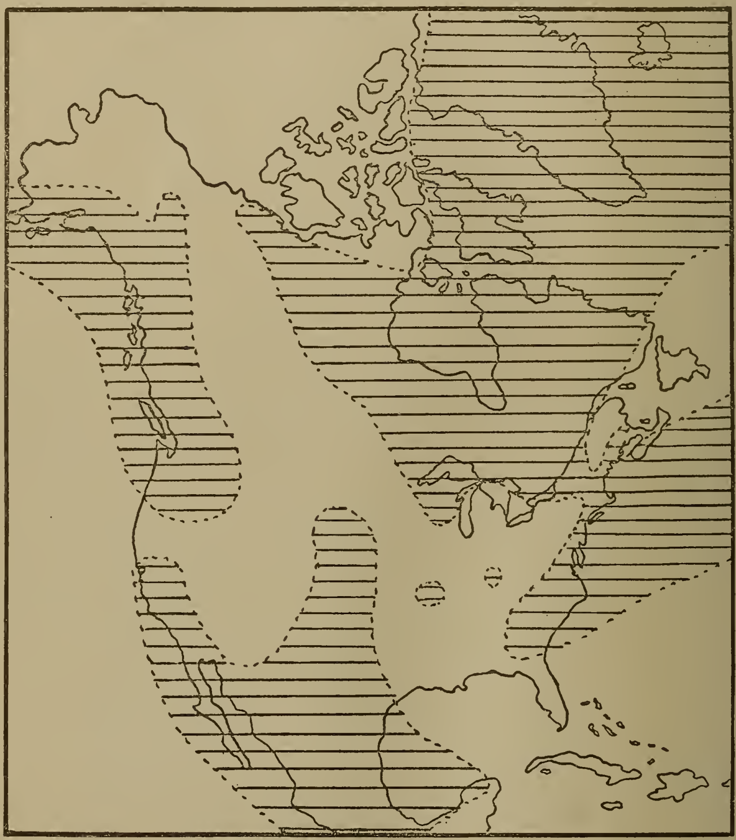


FIG. 18 Generalized map of North America in the Devonic period, showing the relations of land and water. Horizontal lined areas = land; blank areas = water. Only the northern and extreme southeastern portions of the New York State area were land. The western shore of Appalachia was farther west than during the Ordovicic, due to the addition of the Taconic mountain area

shales, all of which were deposited over the whole Devonic basin in New York. Above these come the Tully limestone and Genesee shale which extend from east-central to western New York. Still higher, and forming the summit of the Devonic, are the Portage shales and sandstones and the Chemung (or Catskill) sandstones

Plate 30

Cliff of Lower Devonic (Coeymans) limestone near Indian Ladder, Albany county

From N. Y. State Mus. Bul. 19, pl. 70

Marcellus and Hamilton (Devonic) shales outcropping along the shore of Lake Erie at Athol Springs, Erie county. The rock is dark colored and in thin layers. The smooth, vertical walls are due to a breaking off of rock masses along what are called "joint planes" and which are so common in nearly all rock ledges.

From N. Y. State Mus. Bul. 19, pl. 72

Plate 32

Upper Devonic (Cashaqua and Rhinestreet) shales in the gorge of the Genesee river near Mount Morris. The thin bedded and stratified character of these rocks are well shown.

From N. Y. State Mus. Bul. 118, pl. 4

which extend from the Catskill mountains to western New York.

Except for the comparatively thin Tully formation, the limestone is confined to the Lower Devonic and the lower part is not more than a few hundred feet thick. Thus the great bulk of Devonic rock lies above this limestone and consists of shales and sandstones piled layer upon layer. These latter rocks are clearly land-derived sediments which were washed into the Devonic sea by streams from the Taconics and also probably from land areas which are known to have existed to the north in Canada.

The Devonic strata, from oldest to youngest, abound in the fossils of marine organisms, and some fossil land plants have also been found. Looked upon in a broad way, Devonic life was much like that of the Siluric, though certain fundamental differences are to be noted. Thus the Devonic furnishes the first really authentic evidence of the existence of land plants. Such plants as ferns, lycopods (club mosses), and equisetae (horse tails) grew to be large treelike forms and in considerable profusion. Remains of these have been found in the Devonic strata in New York. All of them belonged to the very simple, nonflowering plants and were closely related to the plants of the next succeeding Carbonic (coal) period. Among the fossil animals especially abundant in the Devonic rocks of the State are: sponges, corals, echinoderms (star fishes), brachiopods, mollusks (including the bivalves, gastropods, and cephalopods), and arthropods (including trilobites and eurypterids). The graptolites became extinct during the early Devonic. One of the remarkable features of the life was the great abundance and variety of fishes, so that this period is commonly referred to as the "Age of Fishes." From the zoological standpoint all the fishes were of simple types, the true bony skeletons of modern fishes being entirely absent. Devonic fish remains in considerable numbers have been found in the State.

Carbonic strata are only very sparingly represented in New York, there being a few small outlying masses in the southwestern portion of the State (Cattaraugus and Allegany counties). Immediately southward, in Pennsylvania, Carbonic strata are developed on a great scale so we can be certain that the Carbonic sea spread over the southern border of New York State. It is quite possible that this sea extended over most of southern New York, but positive evidence, due to absence of strata, is lacking.

The Permic is the last great period of the Paleozoic era, but rocks of that age are nowhere present in New York State.

APPALACHIAN MOUNTAIN REVOLUTION (CLOSE OF THE PALEOZOIC)

The Paleozoic era was brought to a close by one of the most profound physical disturbances in the history of North America. It has been called the Appalachian revolution because at this time the Appalachian mountain range was born out of the sea by upheaval and folding of the strata. Because of the direct effect of this great upheaval upon the history of New York State, a brief description is given.

All through the vast time (probably ten million years) of the Paleozoic era, a great land mass existed along what is now the eastern coast of North America. This land, which has been called Appalachia, had its western boundary approximately along the present coast line, while it must have extended eastward at least as far as the present border of the continental shelf. Concerning the altitude and character of the topography of Appalachia we know almost nothing, but we do know that it consisted of metamorphic rock of Precambric age, and very similar to that of the Adirondacks. The tremendous amount of derived sediments shows that Appalachia was high enough during nearly all its history to undergo vigorous erosion. Although oscillations of level more than likely affected Appalachia, and its western shore line was quite certainly somewhat shifted at various times, nevertheless it persisted as a great land-mass with approximately the same position during all its long history. Its general position is well shown on the map, figure 16.

Barring certain minor oscillations of level, all the region just west of Appalachia was occupied by sea water during the whole Paleozoic era, and sediments derived from the erosion of Appalachia were laid down layer upon layer upon that sea bottom. The coarsest and greatest thickness of sediments was deposited nearest the land, that is along what we might call the marginal sea bottom. At the same time finer sediments, in thinner sheets, were being deposited all over the Mississippi valley region. By actual measurement, in the present Appalachians, we know that the maximum thickness of these sediments was at least 25,000 feet. These are all of comparatively shallow water origin, as proved by the coarseness of sediment, ripple marks, fossil coral reefs etc., and so we are forced to conclude that this marginal sea bottom gradually sank during the process of sedimentation, thus producing what is called a great geosynclinal trough. Perhaps the very weight of accumulating sediments caused this sinking. Finally, toward the close of the Paleozoic era, sinking of the marginal sea bottom and deposition of sediments ceased, and "eventually the trough began to yield to lateral compression and its contained strata were thrown into folds or fractured by great overthrusts. Thus in place of a sinking sea bottom along the shore of the great interior sea, arose the Appalachian mountains, which in their youth may have been a very lofty range rivalling the Alps in height. This range extends from the mouth of the St Lawrence river to Alabama."[1] As a result of this great physical revolution practically all of eastern North America was raised well above sea level, though the more moderately elevated Mississippi valley region was unaccompanied by folding or faulting of the strata.

The effect of the Appalachian revolution upon New York State is of fundamental importance because the whole State, except probably a small area near the mouth of the present Hudson river, was raised well above the sea, and true marine conditions never again prevailed over any part of its area except the extreme southeastern portion.[2] Judging by the vast amount of erosion which took place during the succeeding Mesozoic era, we are safe in our belief that the general elevation of the State at the close of the Paleozoic was at least several thousand feet above sea level. It is also important to note that this great uplift in New York was accomplished without any folding of the strata except along the Hudson valley. The gentle southward to southwestward tilt (dip) of the Paleozoic strata, however, is thought to have been produced at this time due to somewhat greater uplift on the north.

Along the western side of the Hudson valley, folds produced at the time of the Appalachian revolution are plainly visible, though the folding of the rocks here was much less violent than in the Appalachians proper. As a matter of fact these folds are but continuations of those of eastern Pennsylvania, but the compressive force in southeastern New York was too weak to cause much disturbance. Professor Davis has aptly styled these, "Little mountains east of the Catskills." By far the most conspicuous physiographic feature of this folded region is the Shawangunk mountain (ridge) which stands out very prominently and whose

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[1] Scott's Introduction to Geology, second edition, p. 647.

[2] The influx of tide waters along the eastern and northern borders of the State in the Quaternary period presents no exception to this statement because the conditions then were esturaine rather than marine.

very existence is due to the fact that, as a result of the folding and subsequent erosion, the great sheet of hard and resistant conglomerate has been left as a protective cap over the soft Hudson river (Ordovicic) shales (see figure 19). In the Rosendale cement region the effects of the folding are also evident (see figure 10 and plate 33). The folds in the Siluric and Devonic strata of Skunnemunk mountain were also produced at this time. Of course the whole lower Hudson valley was subjected to this mild compressive force but, since all the rocks older than the Siluric were already so greatly disturbed, it is often impossible to see the effects of the Appalachian disturbance. Thus we see that mountain-building forces have affected the rocks of the Highlands-of-the-Hudson at least three times (Precambric, Taconic revolution, and Appalachian revolution); Cambric and Ordovicic strata of the lower Hudson valley twice (Taconic and Appalachian revolutions); and the Siluric and Devonic strata but once (Appalachian revolution).

The extensive faulting or fracturing of the eastern Adirondack and Mohawk valley regions is a matter of no small importance in our discussion of the physical history of the State, because the present major topographic features of those regions are largely dependent upon the faulting. It is generally believed that much of this faulting occurred toward the close of the Paleozoic era, and most likely at the time of the Appalachian revolution, but since considerable faulting certainly occurred later than that time, it is thought best to discuss this whole subject toward the close of the next chapter.

FIG. 19 The main body of the mountain consists of a great thickness of folded Ordovicic (Hudson River) shales and sandstones which are capped by a comparatively thin, but very resistant layer of Shawangunk conglomerate.

After Darton N. Y. State Mus. Rep't 47, 1894, facing p. 540

Chapter 5

MESOZOIC HISTORY

TRIASSIC PERIOD

We have observed that as a result of the Appalachian revolution New York State was raised well above sea level and this was its condition at the opening of the Triassic period. The total absence of any Triassic strata of marine origin makes it quite certain that the continent extended farther eastward than it does today and if so, the old Paleozoic land mass called Appalachia still existed, though probably much diminished in height by this time. The absence of marine rocks, however, does not mean that no deposition of Triassic sediments occurred within the borders of the State, because a remarkable series of nonmarine strata which were accumulated along the Atlantic slope are, in part, shown in southeastern New York (Rockland county and Staten island).

These nonmarine strata are of Upper Triassic age, as told by the fossils, and their present distribution and mode of occurrence clearly show that they were deposited in a series of long troughlike depressions whose trend was parallel to that of the main axis of the Appalachian range. These troughs lay between the Appalachians proper and old Appalachia. The latter also was now partly made up of the greatly worn-down Taconics. The facts that these troughs are truly downwarps, and that they so perfectly follow the trend of the Appalachian folds, make it certain that they were formed by a great lateral pressure which was a continuation of the Appalachian disturbance. Thus the Appalachian mountains still seem to have been growing well into the Triassic period, and while the Paleozoic strata were being folded the surface of old Appalachia, including part of the Taconic region, was also more or less warped, and the downwarps formed the troughs in which the Triassic beds were deposited. One of these troughs extends along the Connecticut river through Connecticut and Massachusetts; another, and the largest, reaches from Rockland county, New York, through northern New Jersey, southeastern Pennsylvania, Maryland, and into northern Virginia; while several smaller ones lie in Virginia and North Carolina. These depressions were most favorably situated for rapid accumulation of thick deposits because of their position immediately between the two great land masses which were being eroded. The sediments derived from the erosion of the young Appalachians were especially abundant because of the vigorous wearing down of the young mountains. A thickness of thousands of feet of nonmarine rocks, mostly red sandstones and shales, was finally accumulated in these basins, and is known as the Newark series. The great thickness of these rocks, from 10,000 to even possibly 15,000 feet, strongly argues for a gradual downwarping of the basins as deposition of sediments went on. It is often stated that these strata were formed in estuaries, but at least in the northern area, from the Connecticut valley to Maryland, many of the layers show sun cracks, rain-drop pits, ripple marks, and remains and footprints of land reptiles. These features show that for the most part the beds were formed in very shallow water such

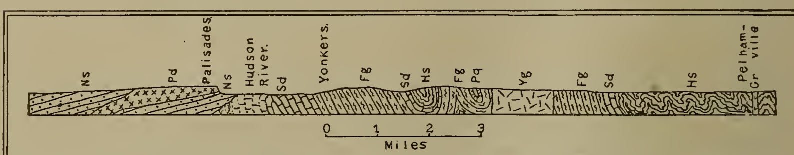

FIG. 20 Detailed section running west-northwest through Pelhamville, Yonkers and the Palisades in southeastern New York, showing the intense folding of Taconic age, the granite dikes, and the relation of the Palisade lava to the other formations. Fg = Fordham fineiss (Precambric); Pq = Poughquag quartzite (Cambric); Sd = Stockbridge dolomite (Cambro-Ordovicic); Hs = Hudson schist (Ordovicic); Yg = Yonkers gneiss; Gr = granite dike; Ns = Newark sandstone (Jura-Trias); Pd = Palisade diabase or lava (Triassic).

Modified from New York City folio, U. S. G. S.

as flood plains or lakes where changing conditions frequently allowed the surface layers to lie exposed to the sun.

During the time of the formation of the Newark beds there was considerable igneous activity as shown by the occurrence of sheets of igneous rocks within the mass of sediments. In some cases true lava flows, with cindery tops, were poured out on the surface and then became buried under later sediments, while in other cases the sheets of molten rock were forced up either between the strata or obliquely through them, thus proving their intrusive character. As a result of subsequent erosion, these lava intrusions often stand out conspicuously as topographic features. Perhaps the most noteworthy of these is the great igneous rock sheet, part of which outcrops to form the famous Palisades of the Hudson and which outcrops altogether for a distance of seventy miles. As shown in

Plate 33

Hydraulic limestone or waterlime of Salina (Siluric) age at the cement quarries 1 mile south of Whiteport, Ulster county. The pronounced tilt of the strata was given at the time of the Appalachian revolution.

From N. Y. State Mus. Bul. 19, pl. 116

Plate 34

Palisades-of-the-Hudson, as seen from Hastings, Westchester county. The rock is a sort of dark colored lava (diabase) which presents a crude columnar structure and rests upon sandstone of Triassic age. The sandstone is largely concealed by the rock debris just above the river level.

From N. Y. State Mus. Bul. 19, p. 4

figure 20, the molten rock sheet first broke through the strata and then crowded its way along parallel to them. During the process of cooling there was contraction which expressed itself by breaking the rock mass into great, crude, vertical columns, and hence the origin of the name "Palisades" (see plate 34). At the base of the Palisade rock, as well as on its top a little back from the edge of the cliff, the Newark sandstone outcrops. The steep cliff is due to the fact that the hard igneous rock is much more resistant to erosion and weathering than the sandstone above and below it.

The rocks of the Newark series are nearly everywhere somewhat folded, tilted and extensively fractured by normal faults. Just when this deformation occurred is not exactly known, but it was probably at the close of the Triassic period as will be shown under the next heading.

Briefly summarized, *the Triassic was a time of accumulation of thick deposits of red sandstone and shale of nonmarine character in troughlike depressions along the Atlantic slope, these deposits being represented in southeastern New York. During their formation there was considerable igneous activity when sheets of lava were forced through or between the strata as is well shown in the case of the rock of the Palisades.*

JURASSIC PERIOD

No rocks of Jurassic age occur within New York State nor as a matter of fact in all eastern North America, except possibly some fresh-water deposits along the Potomac river of Maryland. The failure of such strata is readily explained by the fact that the Jurassic period was ushered in by a slight upwarping (accompanied by faulting and tilting of the rocks) of the Atlantic border of North America so that there were no basins of deposition within the present eastern border of the continent. That this uplift actually occurred and that the Jurassic period in the eastern United States was a time of extensive erosion, is well established because the whole Atlantic seaboard, including the tilted and faulted Triassic strata, was worn down well toward the condition of a peneplain and the next sediments (Cretacic) were deposited upon the eastern portion of that worn-down surface (see figure 22). For instance, on Staten island and in northern New Jersey, the Cretacic beds may be seen resting directly upon the deeply eroded Triassic rocks, and hence the proof is conclusive that during much if not all of the Jurassic period active erosion was taking place, and this in turn implies that the Triassic beds were well elevated in the early Jurassic.

Briefly summarized: *No deposition of Jurassic strata occurred within the borders of New York State but instead, the region was well above water and undergoing active erosion so that by the close of the period this region, as well as the whole Atlantic slope, had been worn down to the condition of a fairly good peneplain.*

CRETACIC HISTORY

The Cretacic period opened with the eastern coast line of the eastern United States somewhat farther out than it now is, but early in that period there was enough subsidence, or possibly warp-

Fig. 21 Generalized map of North America in the Upper Cretacic period, showing the relations of land and water. Horizontal lined areas = land; blank areas = water. The sea then spread over the Atlantic coastal plain region including Long and Staten Islands of New York. During the next (Teritary) period, the conditions were much the same along the Atlantic and Gulf coasts, but in the west the great interior sea had disappeared.

ing, of the coastal lands to allow deposition of sediments over much of the region now known as the Atlantic Coastal plain. That but little downwarping of the surface was necessary in order to produce proper conditions for sedimentation is evident because the coastal lands, just prior to the Cretacic, were already low-lying as a result of the long Jurassic erosion period. There was just enough warping of these low coastal lands to produce wide flats, flood plains, shallow lakes, and marshes back from the real coast line and in which were deposited the sediments derived from the Piedmont plateau and Appalachian areas. The early Cretacic deposits thus formed are known as the Potomac series, and consist of very irregular layers of sand, gravel and clay. The very irregular arrangement of these beds and their rich content of fossil land plants, afford conclusive evidence that the sediments were not accumulated under marine conditions. The Potomac series outcrops at the western margin of the present Coastal plain and has been traced from Martha's Vineyard, through Nantucket, Long Island, Staten island, Northern New Jersey, and southward into Georgia. Passing seaward the strata dip under those of later age (see figure 22). On Long Island, Potomac outcrops occur only along the northwestern border but these beds no doubt dip under the more recent deposits of the rest of the island. The maximum thickness of the Potomac series is only about 700 feet.

Along the Atlantic coast certain deposits which should come between the Lower and Upper Cretacic are missing, and the Upper Cretacic beds rest upon the eroded surface of the otherwise undisturbed Lower Cretacic. Thus we know that there was a gentle upward oscillation of the land toward the end of the Lower, or beginning of the Upper, Cretacic, after which a moderate amount of erosion of the Lower Cretacic beds took place.

Then came another gentle submergence of the coastal lands when the Upper Cretacic strata were formed. The character and present extent of these deposits, and the fact that they are of marine origin, prove that this subsidence allowed a shallow sea to spread over practically all of what is now called the Atlantic Coastal plain including most of Long and Staten islands in New York. *Accordingly we learn that, for the first time since the close of the Paleozoic, did truly marine conditions prevail over any portion of New York State, and also that Appalachia, the great land mass of the east, which had persisted through the many million years of the Paleozoic and most of the Mesozoic, now disappeared under the Cretacic sea.*

The present surface distribution of the Upper Cretacic beds is much like that of the Lower Cretacic, and they also dip under the still later formations of the Coastal plain (see figure 22). The thickness of the Upper Cretacic is never more than a few hundred feet.

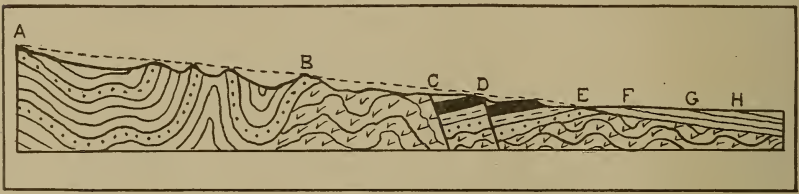

FIG. 22 Diagrammatic section through the Atlantic slope, at about the latitude of northern New Jersey, showing the structures and relations of the various physiographic provinces as they now exist.

A to B = Folded Paleozoic strata of the Appalachian mountains, with hard strata standing out to form the ridges.

B to C = Piedmont plateau consisting of highly folded and metamorphosed rocks of Precambrian and early Paleozoic ages.

C to E = Triassic strata showing tilting and faulting of the beds and mode of occurrence of an igneous rock sheet (D) which outcrops to form a low ridge.

E to H = Coastal plain, consisting of comparatively thin sheets of unconsolidated sediments.

E to F = Cretacic beds (upper and lower).

F to G = Tertiary beds.

G to H = Quaternary beds

H = Present coast line.

The dotted line represents the peneplain character of the surface (except for the tilting) at the close of the Cretacic period.

To summarize: *The Cretacic period opened with slight subsidence of the Coastal plain region, including southeastern New York, to produce low-lying flats upon which the nonmarine Potomac sediments were deposited. Then came a slight reelevation (accompanied by erosion) followed by subsidence of the Coastal plain region enough to allow encroachment of the shallow sea in which the Upper Cretaceous sediments were accumulated.*

LIFE OF THE MESOZOIC

The life of the Mesozoic is but scantily represented within New York State because rocks of that age are so poorly exposed. The Mesozoic era is commonly referred to as the " Age of Reptiles " because animals of that class then reached their culmination of development. During this era the great dinosaur reptiles, the largest land animals that every lived, stalked the western plains. Some remains of smaller dinosaurs have been found in the Triassic beds of the Atlantic coast, one specimen lately having been discovered in the Newark beds along the lower Hudson. Reptilian tracks abound in the Newark strata. Mammals appeared in the early Mesozoic, but throughout the era they continued small and comparatively insignificant. The first birds and true bony fishes (teleosts) appeared in the later Mesozoic, but they are either absent or not important in the Mesozoic of the middle Atlantic coast. The invertebrate life of the era was in general very different from that of the Paleozoic, few types from the latter era having persisted, and by the end of the Mesozoic the invertebrates took on a decidedly modern aspect.

Among plants, those of the early era were still simple nonflowering kinds much like those of the Carbonic or "Coal age," while in the late Mesozoic flowering plants of very modern types, including many of our present forest trees, were prominently developed. The Cretacic beds of the Atlantic coast are rich in fossil plants.

THE CRETACIC PENEPLAIN AND ITS UPLIFT

During all the Mesozoic era most of the eastern portion of the United States was above water and undergoing erosion, so that, as a result of this very long period of wear, the region was reduced to the condition of a more or less perfect peneplain. It is known as the Cretacic peneplain because of its best development during the Cretacic period. This vast plain extended over the areas of the Appalachian mountains, Piedmont plateau, all New York State, the Berkshire hills, and the Green mountains. Its most perfect development was in the northern Appalachians, for example, from east-central Pennsylvania to Virginia, where hard and soft rocks alike had been so thoroughly cut down that no masses projected notably above the level of the low-lying plain.

Farther northward, however, over New York and western New England, its development was less perfect so that certain masses of harder rock stood out more or less prominently above the general level of the plain. In the central and eastern Adirondacks many low mountains of very resistant igneous rock rose above the peneplain surface. In a similar manner an occasional low mountain stood out in the Berkshire Hills region, and it seems probable that the hard Devonic sandstones of the Catskills also rose notably above the peneplain, though in the latter case positive proof has not been given. Thus, *toward the end of the Mesozoic era all the area of New York State had been reduced to a vast, monotonous, featureless plain (peneplain) except for the mountain masses of very moderate elevation in the east-central Adirondack, and possibly also the Catskill, regions.* As Professor Berkey says: "The continent stood much lower than now. Portions that are now mountain tops and the crests of ridges were then constituent parts of the rock floor of the peneplain not much above sea level. This rock floor was probably thickly covered with alluvial deposits (flood plain) not very different in character from the alluvial matter of portions of the lower Mississippi valley of today. Upon such a surface the principal rivers of that time flowed, sluggishly meandering over alluvial sands and taking their courses toward the sea (the Atlantic) in large part free from influence by the underlying rock structure. The ridges and valleys, the hills, mountains and gorges of the present were not in existence, except potentially in the hidden differences of hardness of rock structure. Such conditions prevailed over a very large region, certainly all of the eastern portion of the United States."[1]

In the western part of the United States the Mesozoic era was brought to a close by what must take rank as one of the greatest mountain upheavals in the history of North America. This is known as the Rocky Mountain revolution because the great Rocky Mountain system was chiefly formed at this time. At the same time *in the eastern part of the United States the Mesozoic was closed by an important physical disturbance though on a far less grand scale than that of the west. This disturbance produced an upwarp of the vast Cretacic peneplain with maximum uplift of from two to three thousand feet following the general trend of the Appalachians and thence through northern New York.* This upward movement was unaccompanied by any renewed folding of the strata, and the effect was to produce a broad dome sloping eastward and westward, and northward to the Gulf of St Lawrence and southward to the Gulf of Mexico.

A prominent effect of this great uplift was to revive the activity of the streams so that they once more became active agents of erosion. *We are now prepared to make the important statement that the present major topographic features of New York State, as well as western New England and the whole Appalachian region, have largely been produced by the erosion or dissection of this up-*

[1] N. Y. State Mus. Bul. 146, p. 67.

Plate 35

Looking eastward down the valley of the west branch of the Susquehanna river from a point 2 miles west of Renovo, Clinton county, Pa. The river here cuts across a series of Appalachian ridges and the view was taken from near one of the summits. The remarkable concordance of altitudes or "even sky line" of the ridges is well shown and this uniform level of the ridge tops represents the surface of the upraised Cretacic peneplain.

Photo loaned by W. M. Gaylor, Sag Harbor, N. Y.

Plate 36

Precambric rock in the Highlands of the Hudson. Anthony's Nose and Manitou mountain along the Hudson river. The fairly even sky line of the mountain summits represents the old, upraised Cretacic peneplain.

From N. Y. State Mus. Bul. 19, pl. 8

raised Cretacic peneplain. This being the case, are any remnants of that upraised surface still left? In the affirmative answer to this inquiry we have the most positive evidence for the former existence of the Cretacic peneplain. We have said that the most perfect development of the peneplain was from central Pennsylvania to Virginia, and it is just here where we should expect to find the best remnants of that old surface. In this region the typical Appalachian ridges and valleys, which run parallel to the trend of the mountain range, are very well developed. These valleys are the trenches cut along the belts of soft rock and to below the surface of the upraised peneplain, while the ridges have developed along the belts of hard rock and their summits actually represent portions of the old peneplain surface. These ridges all rise to the same general level for miles around, and as viewed from the summit of any one of them the concordant altitudes give rise to what is called the "even sky line" which is a most striking feature of the landscape. Plate 35 gives an excellent idea of the even sky line across these ridges.

In New York State the concordant altitudes are not so well shown both because the peneplain was here not so perfectly developed and because the attitude of the strata has largely been unfavorable to the formation of long, distinct ridges. Remnants of the peneplain are, however, unmistakably present in New York as, for example, on a very large scale over the great Southwestern plateau whose high points nearly always rise to altitudes of about 2000 feet. This plateau is simply a part of the upraised and dissected Cretacic peneplain, and the slight downward sag toward the middle (already noted in chapter 2) is no doubt due to a slight downwarping of the general level during the process of uplift. The topographic map (plate 4) well illustrates the character of this dissected plateau. The present elevation of the peneplain remnants does not necessarily indicate the maximum amount of uplift. In the next chapter evidence will be presented to show that, for the New York area at least, the land was considerably higher in the Tertiary period than it is at present.

The summit of the Tug Hill province is a small plateau at an altitude of about 2000 feet, and is merely a remnant of the upraised peneplain which was formerly connected with the Southwestern plateau. As one stands at the summit of Tug hill and looks out over the western slope of the Adirondacks, he is impressed by the remarkably even sky line there shown at an altitude of a little over 2000 feet. The east-central Adirondacks and the Catskills present exceptions because these regions stood out above the old peneplain.

The Mohawk and upper Hudson valleys have been so broadly and deeply trenched through soft strata that in them no remnants of the peneplain surface remain. Immediately eastward in the Berkshires, however, the old surface is well exhibited. In the Highlands-of-the-Hudson, a view from one of the high points shows a rather even sky line at an altitude of from 1200 to 1500 feet, the somewhat lower elevation of the old surface here being due to the fact that this region was east of the main axis of uplift.

Since the actual work of erosion or dissection of the upraised peneplain occurred during the Cenozoic era, further discussion of the subject is reserved for the next chapter. It has been the present purpose to prove that the Cretacic peneplain actually existed and that it was upraised.

FAULTING OF THE EASTERN ADIRONDACKS

The eastern and southern Adirondack regions have been extensively fractured or faulted (see figures *23 and 24*). *In fact the major topographic features of those regions such as the numerous north-northeast by south-southwest ridges and valleys are largely*

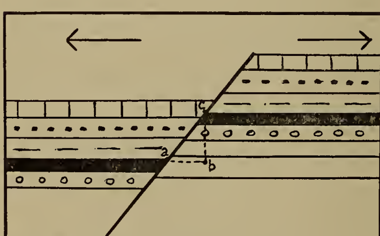

FIG. 23 Cross-section of a normal fault.

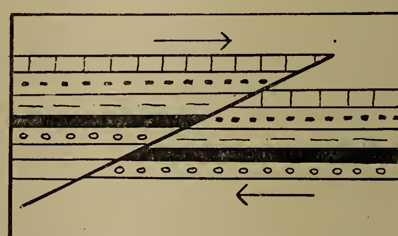

FIG. 24 Cross-section of a reversed or thrust fault.

dependent upon this faulted structure. These fractures are all of the normal fault type with fault surfaces practically vertical. Examination of the topographic maps of the whole eastern and southern Adirondacks shows that by far most of the ridges and valleys, streams and lakes trend in a north-northeast by south-southwest direction, or perfectly parallel to the direction of the major faults. Up to the present, no single fault has been proved to extend across the entire region, but rather there is a series of numerous parallel faults, no one of which has been traced much over 20 or 30 miles. The exact amount of displacement along these lines of fracture in the ancient crystalline rocks can not be determined, but many times it amounts to at least 2000 feet.

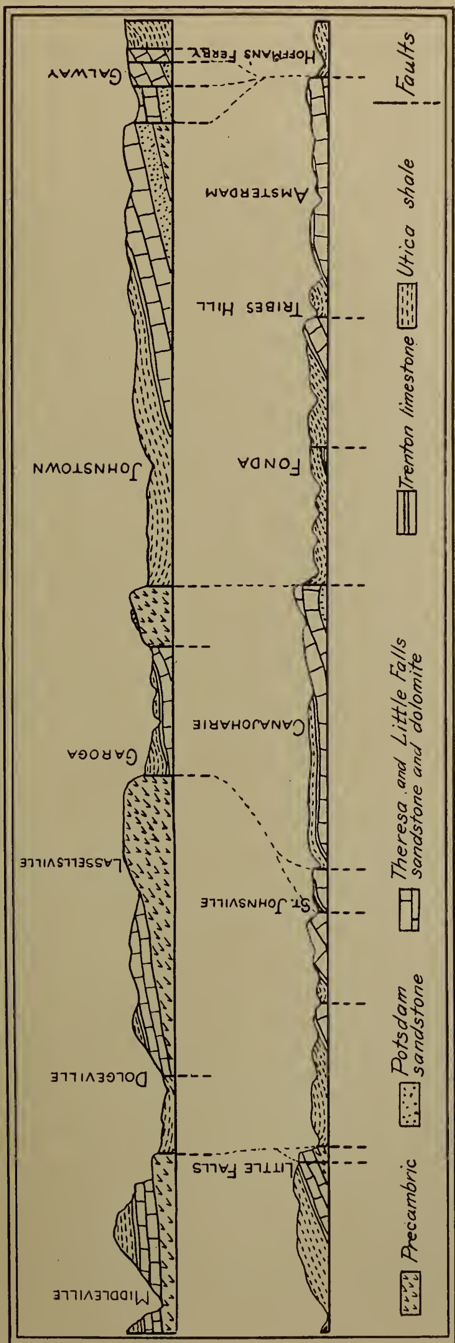

Fig. 25 Cross-sections of Mohawk valley faults. Lower section along the Mohawk river; upper section along a zone from 8 to 10 miles farther north. Length of each section 52 miles; vertical scale greatly exaggerated.
Modified after Darton, Annual Rep't N. Y. State Geol., 1894

This series of faults cuts through the early Paleozoic strata along the shores of Lake Champlain and in the Mohawk valley, and in these regions, due to marked differences in the rocks affected, it has been possible to determine carefully the character of the faults and the amounts of the displacements (see plate 37). Figure 25 shows two sections through the faulted region of the Mohawk

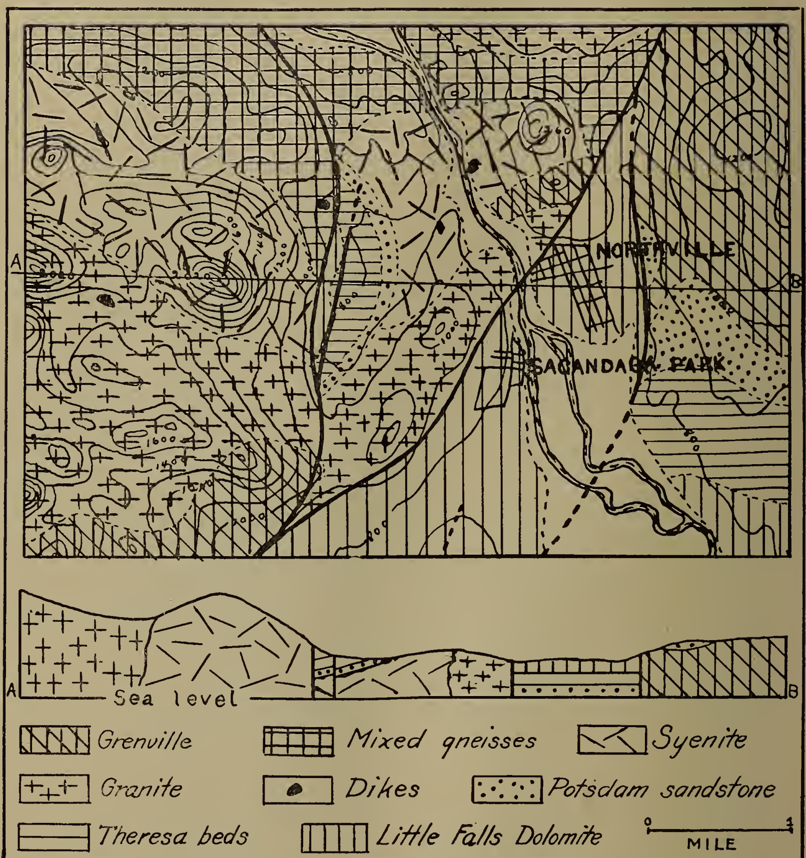

FIG. 26 Geologic and topographic map of the vicinity of Northville (Fulton county), showing an unusual variety of rock formations and structures along the southern border of the Adirondacks where the Precambric and Paleozoic rocks come together, and where all have been greatly faulted. The position of the structure section is indicated by the line AB, the vertical scale of the section being twice exaggerated. The greatest fault is the one on the west, and the country immediately on the east side of it has dropped fully 1500 feet with respect to that on the west (mountain) side. Northville lies between two smaller faults and on an earth block which has dropped several hundred feet with respect to the country on either side.

Geology by W. J. Miller, N. Y. State Mus. Bul. 153

Normal fault in bank of East Canada creek near Manheim, Herkimer county. The heavy beds on the left are Little Falls dolomite and the thin beds on the left are Trenton limestone. The steep tilt of the Trenton strata was caused by friction producing a sort of up-drag effect, during the slipping of the rock masses. The hole is artificial.

From N. Y. State Geol. Rep't 1894, pl. 4, facing p. 4

valley. To a considerable degree the topography of the valley is affected by the faults, especially where the harder Precambric or Cambric rocks form the scarp or upthrow sides of the faults. This is particularly true at Little Falls and the "Noses" (near Yosts) where, in each case, the Mohawk river has cut a gorge across a prominent fault scarp and even down to the underlying Precambric rock which has been brought relatively nearer the surface by the tilting of the earth blocks (see figure 7). On the geologic map of the State (figure 1) two tongues of Paleozoic rock are seen to extend northward well into the Precambric rock area, and these are to be explained by the fact that, due to faulting along the west sides, the Paleozoic strata, for fifteen or twenty miles, have dropped down (relatively) fully 1500 feet with respect to the Precambric rock. The much more resistant Precambric rock has stood out against erosion and in each case rises with steep front from 1000 to 1500 feet above the Paleozoic rock surface (see figure 26). The small remnant of Paleozoic strata already referred to at Wells in Hamilton county was dropped down fully 2000 feet by faulting against the Precambric rock just west, and thus this remarkable Paleozoic outlier has been preserved from complete removal by erosion.

What is the age of the faulting or, in other words, when were these fractures developed? That some faulting, at least, occurred during Precambric time has been well established but, so far as known, those faults are of very minor importance, certainly having no appreciable influence upon the existing topography.

During the Paleozoic era, however, there is good reason to think that considerable faulting took place. At just what time during the era the faulting occurred is not now altogether certain, but it is certain that it was sometime after the deposition of the Ordovicic sediments because at many places those rocks are involved in the faulting. Cushing has suggested that the faulting may have been initiated at the time of the Taconic revolution when the rocks of the region immediately eastward were so greatly disturbed, but he says, "the great earth disturbances (Appalachian revolution) which prevailed in the Appalachian zone toward the close of the Paleozoic would seem more likely to have brought about the major faulting of the reigon."[1] At this latter time the rocks of northern New York were not folded but, as we have learned, the whole State was notably elevated, and during this disturbance conditions were cer-

[1] N. Y. State Mus. Bul. 95, p. 405.

tainly favorable for extensive fracturing of the strata. The disturbance of the early Mesozoic, which caused the fracturing of the Newark (Triassic) rocks along the Atlantic slope, quite certainly did not affect the Adirondacks because those faults are of a different type and closely confined to the Triassic basins.

If the major faulting occurred at the close of the Paleozoic, then the Mesozoic must have opened with the northeastern portion of the newly upraised New York State area cut by a great series of faults which caused the edges of the upturned earth blocks to stand out prominently as ridges. However this may have been, we are certain that by the close of the long period of Mesozoic erosion the old fault scarps or ridges were practically obliterated. If so, how do we account for the present Adirondack ridges which follow the fault lines? As a result of the uplift of the Cretacic peneplain one or both of the following things happened, either there was renewed faulting, or that as a result of unequal erosion (due to differences in rock character) on opposite sides of the faults, the old fault scarps were renewed. It is quite certain that both things occurred, and thus the surface of the newly elevated Cretacic peneplain in northeastern New York was made irregular by freshly formed fault scarps. This, together with the later (Cenozoic) erosion along the old fault lines and belts of weaker rocks, accounts for the existing Adirondack ridges. That some of the faulting actually dates from this time, or possibly even later, is proved by the present existence of certain steep fault cliffs in perfectly homogeneous rock masses, and by the fault blocks which have been scarcely modified by erosion since their formation.

DRAINAGE OF NEW YORK IN THE MESOZOIC

Thus far we have said very little about the early drainage features of New York State. In fact we must admit that prior to the Cenozoic era, we have practically no knowledge concerning the positions of even the major drainage lines of the State. From our knowledge of the land and water relations during the Paleozoic era, we can form only the most general ideas regarding the drainage. The Mesozoic physiography of the State is better known and hence the drainage is perhaps better known, but even here positive knowledge is almost wholly lacking. The whole subject of the Precenozoic drainage of New York is one which demands thorough study before anything like satisfactory conclusions can be reached, and the following very brief discussion is intended to be merely suggestive of the problems involved.

At the close of the Paleozoic, and as a result of the Appalachian uplift, the region of New York State was raised well above sea level, with the greatest uplift toward the north as shown by the general south to southwesterly dip (tilt) of the Paleozoic strata (see figures 3 and 5). At that time those strata lapped over much of what is now the Precambric rock area of the Adirondacks. The Appalachian folds of the Hudson valley region, as well as the highlands (of earlier origin) in general along the eastern border of the State, must have prevented any important eastward drainage. Thus, in the writer's belief, the strongest evidence suggests that the principal streams of the early Mesozoic era flowed in general southwesterly courses upon the surface of the newly upraised Paleozoic strata and away from the highlands of the eastern border of the State.[1]

If this be the correct interpretation (for others are certainly possible) of the early Mesozoic drainage, it must follow that no river at all comparable in length and position to the present Hudson could have existed along the eastern side of the State, and no large rivers, like the Susquehanna and Delaware, then had southeasterly courses across the Appalachian mountains.

During the long Mesozoic era, the area of the State was profoundly eroded, as already proved. In the midst of this era the ruggedness of Mesozoic relief reached its maximum and, in accordance with well-known principles, the valleys must have formed along the belts of softer rock, while the harder rocks stood out to form the highlands or ridges. At this time the edges of the Paleozoic strata had sufficiently retreated (by erosion) on all sides from the central Adirondacks so that a considerable area of Precambric rocks had already become exposed in northern New York. During this retreat of the Paleozoic strata there was a tendency to form important valleys, especially along the western and southern borders of the Adirondacks, because whenever the harder rock formations were encountered they would stand out as escarpments, while the softer rocks would be worn down into valleys. It is in accordance with these principles that the Mohawk and Black river valleys were formed, though it does not necessarily follow that these older valleys occupied the same positions as the present ones because of the gradual retreat of these depressions away from the Adirondack region.

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[1] It should be stated that the Great Lakes were not then in existence, those bodies of water not having been formed till late in the Cenozoic era (see chapter 6).

In western New York and over the region of the present Lake Ontario, the hard and soft early Paleozoic strata outcropped along a nearly east and west direction, and hence considerable streams, tributary to the major southwestward flowing streams, doubtless followed the belts of soft (shale) rocks. Such a west-flowing stream may have followed the belt of weak Ordovicic shales which runs under the present Lake Ontario.

In southeastern New York, in the midst of the Mesozoic era, the land was lower than at the beginning of the era as shown by the fact that the late Cretacic sea spread over at least some of the region. This gave a better opportunity for the development of an eastward or southward drainage toward the Atlantic basin, and at this time it is possible that the ancestors of the modern Hudson, Delaware, and Susquehanna rivers were formed.

However uncertain our ideas may be regarding the topography and drainage of the early and middle Mesozoic, we are nevertheless sure that by the close of the period the topography of the State was that of almost a peneplain which has already been described, and that the streams were all of low gradient and very sluggish. During the long erosion time of the Mesozoic, there must have been many changes in stream courses and adjustments to rock structures. By the close of the era the courses of the rivers are, as yet, not definitely known, though in accordance with the above discussion we are reasonably certain that the principal drainage of the State from the northern, central, and western portions was southwestward to westward into the Mississippi basin, while the drainage of the southeastern portion was southward to southeastward into the Atlantic basin.

Chapter 6

CENOZOIC HISTORY

TERTIARY PERIOD

Rock formations and life of the Tertiary The Mesozoic closed and the Cenozoic opened with the uplift of the great Cretacic peneplain. Before the uplift, the sea spread over the Long and Staten Islands region, but for a time after the uplift the land was there high enough to exclude the sea and New York State was wholly above sea level. This we know because the lowest (earliest) Tertiary deposits do not occur on Long or Staten Islands or in northern New Jersey, and hence the region must have been above water. The subdivisions of the Tertiary, from oldest to youngest, are known as Eocene, Miocene, and Pliocene. The early Eocene deposits are missing from the northern Atlantic Coastal plain, and on Long and Staten Islands we have no evidence that any of the Eocene is present which thus leads to the conclusion that all southeastern New York was dry land during the whole of the Eocene. During the Miocene there was enough sinking to allow the sea to encroach over the Long and Staten Islands districts as well as the whole northern Coastal plain. Except for very slight oscillations of level which we shall here disregard, the region remained submerged under shallow sea water during all the Miocene and Pliocene, or till the close of the Tertiary period. The Tertiary deposits were sands, gravels, and clays which formed layer upon layer in the shallow sea along the margin of the continent (see figure 22), but on Long and Staten Islands they are seldom seen because of the more recent covering of glacial deposits. They are finely exposed in the Coastal plain of New Jersey.

The Tertiary period is generally called the "Age of Mammals" because, although mammals began in a small way in the Mesozoic, they became the dominant feature of life for the first time in the Tertiary. In the early Tertiary the mammals were very different in appearance from those of the present, a common form then being a generalized or ancestral type (for example, Phenacodus) about the size of a dog and having five toes. Many of our modern mammals have descended from this type. During the Tertiary the mammals developed very rapidly so that by the close of the period they were very much as they are today except that man, the highest and most wonderful animal of all, did not appear until the last (Quaternary) period of earth history. Birds developed to much like their present forms. Reptiles diminished both in size and number of species in a remarkable way, while fishes took on a decidedly modern aspect. The invertebrates of the Tertiary were not strikingly different from those of the present and by the close of the period they were so modern that from 75 to 90 per cent of them were even the same species as those now living.

We learned that, in the late Mesozoic, true flowering plants had been developed in abundance, and during the Tertiary these and all other plants reached a development which in no essential way was different from that of the present.

The records of Tertiary life are but scantily represented in New York because of the small extent of exposed Tertiary rocks. In the deposits of the Atlantic Coastal plain, however, abundant fossils are found.

Development of relief features. The uplift of the great Cretacic peneplain was an event of prime importance for New York because it literally furnishes us with the beginning of the history of most of the existing relief features of the State. Hence we assert with emphasis that all the principal topographic features of the State as we see them today date from the uplift of the Cretacic peneplain because they have been produced by the dissection of that upraised surface. This dissection was largely the work of erosion, though in the eastern Adirondack region faulting has produced notable effects. All the great valleys such as the Champlain, St Lawrence, Black river, Mohawk, and Hudson have been produced since the uplift of the peneplain. It should also be stated that the Great Lakes, as well as the numerous lakes, gorges, and waterfalls for which New York is noted, were absent as geographic features at the opening of the Cenozoic.

As previously stated, the streams of New York which flowed upon the peneplain surface sluggishly meandered over deep alluvial or flood-plain deposits, and their courses were little if any determined by the character of the underlying rocks because hard and soft rocks alike were worn down to a general level. The uplift of the peneplain, however, greatly revived the activity of the streams so that they became very effective agents of erosion; they first cut channels through the alluvial deposits and then into the underlying bedrock. Thus these large original streams had their courses determined in the overlying deposits, and when the underlying rocks were reached the same courses had to be pursued entirely without reference to the underlying rock character and structures. Such streams are said to be superimposed because they have, so to speak, been let down upon the underlying rock masses. To quote Professor Berkey: "The larger rivers, the great master streams, of the superimposed drainage system, in some cases were so efficient in the corrasion of their channels that the discovery of discordant structures (in the underlying rocks) has not been of sufficient influence to displace them, or reverse them, or even to shift them very far from their original direct course to the sea. They cut directly across mountain ridges because they flowed over the plain out of which these ridges have been carved and because their own erosive and transporting power have exceeded those of any of their tributaries or neighbors."[1] Fine examples of such superimposed streams which are now entirely out of harmony with the structure of the regions over which they flow are the Susquehanna, Delaware, and Hudson. Thus the Susquehanna cuts across a whole succession of Appalachian ridges while, in accordance with the same explanation, the Delaware cuts through the Kittatinny range at the famous Delaware Water Gap. The lower Hudson pursues a course no less out of harmony with the structure of the country through which it passes. Thus it flows at a considerable angle across the Taconic folds above the Highlands, after which it passes through a deep gorge which it has cut through the hard granites and other rocks of the Highlands. The simple explanation is that the Hudson had its course determined upon the surface of the upraised Cretacic peneplain, and that it has been able to keep that course in spite of the discordant structures of the underlying rocks.

But while the great master streams were thus cutting deep trenches in hard and soft rock alike, numerous side streams or tributaries came into existence and naturally developed along the belts of weak rock and in harmony with the geologic structures. This is true of all the streams now occupying the valleys between the Appalachian ridges. In southeastern New York two remarkable cases are presented by the Wallkill river and Rondout creek which flow many miles northeastwardly and in a direction almost the reverse of that of the Hudson to which they are tributary. As the master superimposed Hudson cut its channel deeper and deeper, the Wallkill and Rondout side streams were enabled to cut their valleys deeper and deeper while they increased in length by pushing

[1] N. Y. State Mus. Bul. 146, p. 69.

their headwaters farther southward, but only along belts of weak rock and in harmony with the northeast-southwest folded structure of the region.

In a similar manner the great Mohawk valley has been developed. The Mohawk is the chief tributary of the Hudson, and whether or not its ancestor flowed in about the same position upon the surface of the peneplain, we do know that the present Mohawk valley (below Little Falls) has been carved out of the upraised peneplain by the Mohawk river and its tributaries along a belt of weak Ordovicic shales. The valley is bounded on the north by the very hard Precambric rocks and on the south by the fairly resistant limestones of the Helderberg escarpment. Proof will be given on a later page for the statement that late in the Tertiary (that is just prior to the great Ice age) the Mohawk river had its source near Little Falls, and that at the same time another stream (Rome river), now extinct, flowed westward from Little Falls, past Utica and Rome and into the basin now occupied by Lake Ontario. West Canada creek was then tributary to the Rome river, while the Sacandaga river flowed into the Mohawk instead of the Hudson as it now does.

However uncertain we may be as to the location of a Precenozoic Susquehanna river, we are very certain that the present numerous, deep channels of the Susquehanna drainage system have been cut into the upraised peneplain. The Susquehanna, like the Hudson, is a good example of a superimposed stream and its ancestor may have flowed along the same general course over the low-lying peneplain before its uplift. Immediately after the uplift some of the more easterly headwaters of the Susquehanna came out of the southern Adirondacks. Evidences of this are as follows: (1) The present Mohawk valley had not been formed, the Mohawk river then having only begun the westward migration of its headwaters along the belt of soft shales; (2) the natural slope of the southern Adirondack region was then southward into the east branches of the upper Susquehanna; and (3) the positions of the present sources of the east branches of the Susquehanna at the crest of the high Helderberg escarpment, and in some cases within a very few miles of the present Mohawk river (see drainage map, figure 11) strongly argue for the cutting off or beheading of the former headwaters of the east branches. This beheading was accomplished by the Mohawk as its headwaters migrated slowly westward thus tapping one by one of the upper waters of the east branches of the Susquehanna. Even today the Mohawk continues to steal drainage territory at the expense of the Susquehanna because the short, swift tributaries of the Mohawk, which flow northward over the Helderberg escarpment, are cutting down their channels rapidly, while their headwaters are migrating southward into the territory of the Susquehanna. A great network of large and small streams tributary to the upper Susquehanna drain a considerable portion of south-central New York, there being no single great master stream in this region because the rock formations are so nearly horizontal and are so much alike as regards resistance to erosion.

The Delaware system has had a history practically the same as that of the Susquehanna, except that it never drained any of the region north of the Mohawk.

The present ruggedness of the Catskills is largely, if not altogether, due to the production of deep channels which have been cut into the region upraised at the time of the uplift of the great peneplain by the headwaters of the Delaware, Schoharie creek (north-flowing), and the smaller streams flowing across the steep eastern front of the mountains.

During Tertiary times Lake Champlain was certainly not in existence, but the great depression was there and was no doubt largely developed or at least increased in depth by the settling of earth blocks during the time of extensive faulting at the close of the Mesozoic or beginning of the Cenozoic. The depression is essentially a fault trough. The major stream occupying this valley flowed northward and in late Tertiary time, at least, the divide between the drainage of this and the Hudson valley passed between Glens Falls and Whitehall, and through the present position of the "Narrows" of Lake George, the lake, of course, not then being in existence.

Drainage of New York in the Tertiary. The outline of the probable drainage condition of western New York during the Mesozoic has already been given, and now as we attempt to restore the drainage conditions of the Tertiary, we must admit that some problems yet remain unsolved. Lakes Ontario and Erie certainly were not in existence. Streams flowed through these basins, which were not as deep as they now are. The bottom of Ontario is as much as 491 feet below sea level, while its surface lies at an altitude of 247 feet, and the altitude of Erie is 573 feet while its greatest depth is 204 feet. The explanation of the increased depths of the basins is given on a later page. The question now arises, Did the waters from western New York drain westward or southwestward and into the Mississippi, or northeastward through the St

Lawrence? According to J. W. Spencer, the St Lawrence received those waters, but in the light of what we have said about Mesozoic drainage, and also in view of the fact that the St Lawrence now, in the Thousand Islands region, does not flow through anything like a distinct channel (see plate 9) cut out by a great river, we must admit that there is little to favor such northeastward drainage from western New York. The St Lawrence is almost certainly postglacial in its course at the Thousand Islands as shown by the lack of any real channel, and by the presence of a belt of hard Precambric rock extending across the river and connecting the Adirondacks with the Canadian Precambric rocks. This hard rock belt must have formed a preglacial divide until the recent formation of Lake Ontario and the downwarping of the land which allowed the drainage to pass over the divide for the first time (see later page).

Grabau's interpretation is that the Tertiary drainage of western New York passed westward and southwestward into the Mississippi, and this view is, in the writer's belief, far more tenable. The accompanying map (figure 27) gives a good idea of the drainage lines according to this view. The major drainage lines were no doubt inherited from the Mesozoic, the southwestward courses having been originally determined by the tilt of the land at the time of the Appalachian uplift. When the Cretacic peneplain was upraised, these major streams as, for example, the Dundas river, again began very active work of erosion, and tributary streams were developed, during the Tertiary, along the belts of weak rocks. Thus an important west-flowing tributary was developed along the belt of soft Ordovicic and Medina shales, and formed a channel where the basin of Lake Ontario now is. The Rome river, with source at Little Falls, became a branch of this stream while another important branch had its source on the Thousand Islands divide. There is also shown the position of the Black river, which by late Tertiary had already carved out that important valley and flowed into the Ontario depression, according to Grabau. More recent evidence, however (see later page), strongly favors the passage of the lower end of the Black river north and northeastward into the precursor of the modern St Lawrence, and which had its source on the Thousand Islands divide.

On the accompanying map the three south-flowing streams, one heading near Rochester and the other two flowing through Lakes Seneca and Cayuga, are, in the writer's judgment, not properly shown for the late Tertiary, that is, just prior to the great Ice age.

It is practically certain that preglacial streams were here north-flowing rather than south-flowing, because during long Tertiary time such tributaries to the large stream in the Ontario basin must have developed across the steep north slopes of the Niagara and Helderberg escarpments, and also because the slope of the Genesee

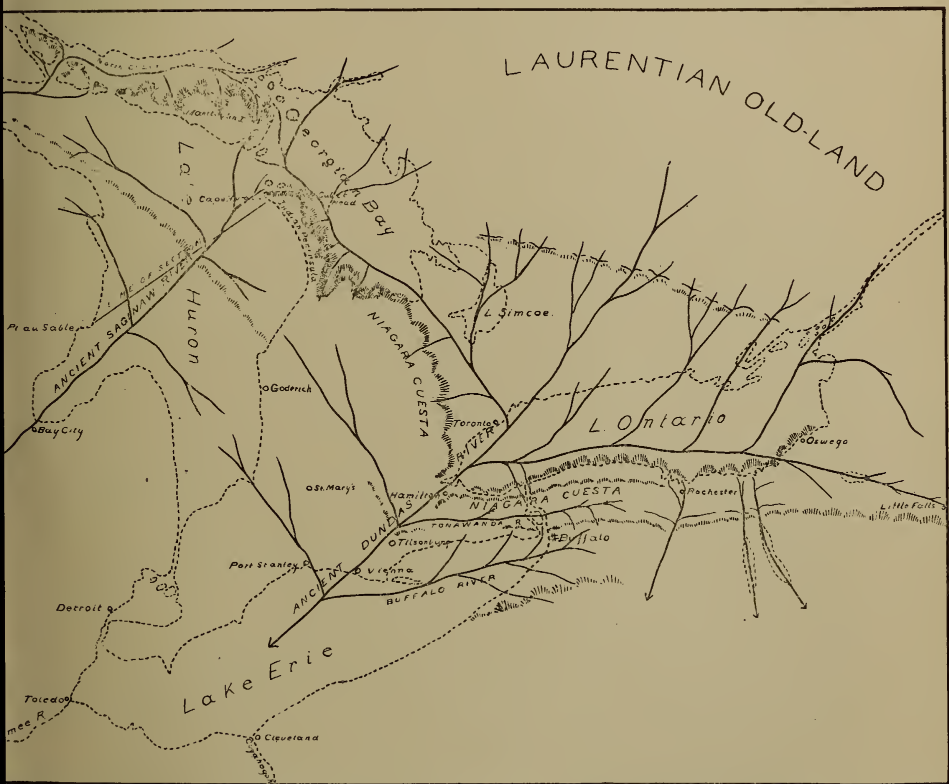


FIG. 27 Grabau's interpretation of late Tertiary drainage in the eastern Great Lakes region, the intention being to show the general kind of drainage rather than the exact location of the streams. The "Rome" river with source at Little Falls is well shown. The three south-flowing streams should, in the writer's opinion, be represented as north-flowing, at least immediately prior to the great Ice Age.

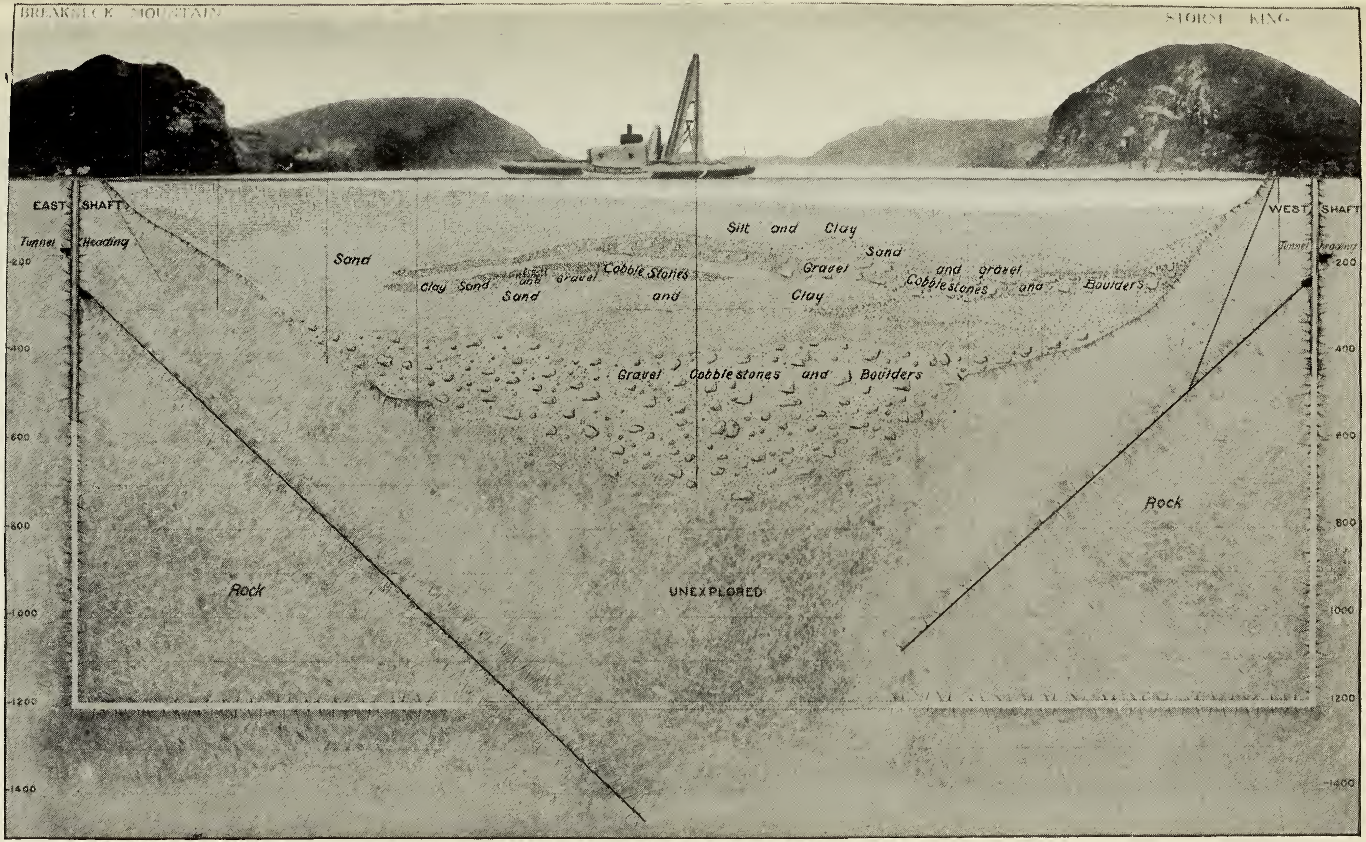
After Grabau, N. Y. State M s. B. l. 45, fig. 6

river is now, at least, so decidedly downward toward the north. If the late Tertiary Genesee flowed southward, the reversal of its course must have been caused by a very marked tilting of the land, but we have no evidence for such a decided land movement.

In our discussion of Mesozoic drainage (see chapter 5) we found that, during the early part of that era, nearly all the drainage of the state passed southwestward to westward into the Mississippi valley with very little, if any, drainage into the Atlantic. But by the close of the Mesozoic, or the beginning of the Tertiary, a considerable south to southeastward drainage had been established along the lines of the Hudson, Susquehanna, and Delaware rivers. Have we any explanation for the establishment of these important drainages into the Atlantic? One view is that the courses came about as a result of the meandering and changing of channels on the surface of the low-lying Cretacic peneplain, and that these courses were maintained upon the upraised peneplain. Another view which the writer would suggest as worthy of consideration is that the south and southeasterly drainage lines were established as a result of the uplift of the peneplain. Chapter 5 shows that the axis of greatest uplift passed through northern New York from central Pennsylvania, the region of southeastern New York and northern New Jersey not being raised so high. It is very reasonable, if not highly probable, that this very warping or slow arching up of the peneplain surface inaugurated the present drainage toward the Atlantic because the streams, no matter what their previous courses, then naturally must have flowed down that initial slope toward the Atlantic.

After the uplift of the peneplain the larger streams cut down their channels most rapidly and would be the first to reach "grade," that is, a condition in which, because of low velocity, they could no longer cut down their channels, though the widening process could continue because of side cutting due to meandering of the streams back and forth from one side to the other of the channels. The deep but broad-bottomed, stream-cut valleys so common in New York State show that many of the streams had reached a graded or nearly graded condition even by the close of the Tertiary. In southeastern New York, at least, we have evidence to show that after the streams had reached grade there was an appreciable renewed uplift of the land which again revived the activity of the streams. Thus the broad Hudson valley, with minor hills rising above its surface, was produced when the Hudson was well along toward a graded condition and then, as a result of this late Tertiary uplift of the land, the present narrow and fairly deep inner channel (gorge) of the Hudson was formed. The Hudson did not reach grade in this inner channel, its work having been interrupted by the spreading of the great ice sheet over the region. It is not known

Plate 38



A composite diagrammatic cross-section of the Hudson gorge at the entrance to the Highlands-of-the-Hudson between Storm King and Breakneck mountains. The shaft and tunnel (at a depth of 1200 feet) show the position of the New York City aqueduct. The bottom of the old Hudson channel is seen to be deeply buried under clay, sand, gravel and boulders. The center boring has penetrated more than 700 feet without striking the old rock bottom. The depth of the rock channel here is more than 2000 feet or from the top of Storm King to the bottom of the buried channel. From N. Y. State Mus. Bul. 146, pl. 14

that this late Tertiary reelevation notably affected the rest of the State.

This inner gorge of the Hudson valley has been traced for fully 100 miles eastward beyond the mouth of the present river. The Coast and Geodetic Survey has made a detailed map (see figure 28) of the ocean bottom near New York City, and the submerged channel of the Hudson river is clearly shown as a distinct trench cut

FIG. 28 The submerged Hudson River channel, whose position is clearly shown by the contour lines. Figures indicate depth of water in fathoms. Data from Coast and Geodetic Survey.

into the continental shelf. Even in the Hudson valley above New York City, the narrow inner rock channel has a depth of hundreds of feet (see plate 38) and is mostly submerged below tide water. Without any question this submerged Hudson channel was cut when the region was dry land, and thus we have positive proof that late in the Tertiary, and possibly extending into the early Quaternary, the region of southeastern New York was notably higher than it is today. Conservative estimates place the amount of elevation greater then than now at not less than 2000 feet because the very end of the Hudson channel is submerged to that extent.[1] The coast was then at what is now the edge of the continental shelf or platform about 100 miles east of the present coast line. That this greater altitude was before the Ice age is proved by the fact that the inner Hudson channel now contains much glacial debris filling. That all of New York State was then higher than now is quite certain because, for example, with the lower Hudson region considerably elevated, the upstate region must also have been elevated (though possibly not so much) in order to maintain the gradients of the actively eroding streams.

To summarize briefly the drainage and physiography of the State during the Tertiary, we may say that, with a certain few important exceptions, the major features as we see them today were practically the same toward the close of the Tertiary, and that these relief features were developed by erosion which began with the uplift of the great peneplain at the opening of this period or the close of the one just preceding. A few of the more notable differences between the drainage of the late Tertiary and the present are as follows: Very few, if any, lakes, waterfalls, or gorges existed; Lakes Erie and Ontario were absent and these basins contained important streams which appear to have drained westward into the Mississippi; the St Lawrence river probably had its source in the Thousand Islands region; the Mohawk river had its source on the divide at Little Falls, while the so-called Rome river flowed westward from Little Falls; West Canada creek entered the Rome river; the Sacandaga river entered the Mohawk; the State, especially the southeastern portion, was notably higher (perhaps not less than 2000 *feet) than it now is so that the Atlantic coast line was about* 100 *miles farther out where the Hudson emptied into the ocean; and Long and Staten islands did not then exist as such.*

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[1] It has been suggested by Chamberlain and Salisbury (Geology, vol. 1, page 529) that the very end of the Hudson, and other submerged channels, may have been deepened by tidal scouring and, if so, the figure (2000 feet) generally given may be too high. At any rate the Hudson channel at the Highlands is submerged nearly 800 feet which certainly implies an altitude of more than 1000 feet greater than now when the river was actively eroding.

Glaciated surface of Onondaga (Devonic) limestone at Cheektowaga, Erie county. The passage of the great ice sheet over this ledge of rock wore it down to a generally smooth surface, except for the scratches which were produced by the abrasion of small rocks or pebbles at the bottom of the ice.

From N. Y. State Mus. Bul 19, pl. 94

QUATERNARY PERIOD, INCLUDING NEW YORK IN THE GREAT ICE AGE

The fact of the Ice age. The Quaternary is the last great period of earth history, and it still continues for it has led up to the present-day conditions. This period was ushered in by the spreading of vast ice sheets over much of northern North America and Europe, which must take rank as one of the most interesting and remarkable occurrences of geological time. On first thought the existence of such vast ice sheets seems unbelievable, but the Ice age occurred so short a time ago that the records of the event are perfectly clear and conclusive. The fact of this great Ice age was discovered by Louis Agassiz in 1837, and fully announced before the British Scientific Association in 1840. For some years the idea was opposed, especially by advocates of the so-called iceberg theory. Now, however, no important event of earth history is more firmly established and no student of the subject ever questions the fact of the Quaternary Ice age.

Some of the proofs of the former presence of the great ice sheet are as follows: (1) polished and striated rock surfaces (see plate 39) which are precisely like those produced by existing glaciers, and which could not possibly have been produced by any other agency; (2) glacial boulders or "erratics" which are often somewhat rounded and scratched, and which have often been transported many miles from their parent rock ledges; (3) true glacial moraines, especially terminal moraines, like that which extends the full length of Long Island and marks the southernmost limit of the great ice sheet; and (4) the generally widespread distribution over most of the glaciated area of heterogeneous glacial debris, both unstratified and stratified, which is clearly transported material and typically rests upon the bedrock by sharp contact.

Ice extent and centers of accumulation. The best known existing great ice sheets are those of Greenland and Anarctica, especially the former which covers about 500,000 square miles. This glacier is so large and deep that only an occasional high rocky mountain projects above its surface, and the ice is known to be slowly moving outward in all directions from the interior to the margins of Greenland. Along the margins, where melting is more rapid, some land is exposed, but often the ice flows out into the ocean where it breaks off to form large icebergs.

The accompanying map (figure 29) shows the area of nearly 4,000,000 square miles of North America covered by ice at the time of maximum glaciation, and also the three great centers of accumulation and dispersal of the ice. The directions of flow of the ice from these centers have been determined by the study of the directions of a very large number of glacial striae or scratches.

FIG. 29 Map of North America showing the maximum extent of the great ice sheets of the Quaternary period. The three great ice centers are shown by the letters as follows: L = Laborador or Laurentide Glacier; K = Keewatin Glacier; and C = Cordilleran Glacier. All of New York State, except probably the very southern border of Long Island and the southern part of Cattaraugus county, was buried under the ice.

It was the Labradorean or Laurentide ice sheet which spread southward over New York to cover all the State except the southern border of Long Island. It must of course be remembered that the north Atlantic coast line was then considerably farther out than now because of the greater elevation of the land.

Direction of movement and depth of ice in New York. The fact that glacial ice flows as though it were a viscous substance is well known from studies of present-day glaciers in the Alps, Alaska, or the Greenland ice sheet. A common assumption, either that the land at the center of accumulation must have been thousands of feet higher or that the ice there must have been immensely thick, in order to permit flowage so far out from the center, is not necessary. For instance, if one proceeds to pour viscous tar slowly in one place upon a perfectly smooth (level) surface, the substance will gradually flow out in all directions, and at no time will the tar at the center of accumulation be very much thicker than at other places. The movement of the ice from one of the great centers was much like this, only in the case of the glacier the accumulation of snow and ice was by no means confined to the immediate centers of accumulation.

When the Labradorean ice sheet spread out southward as far as northern New York, the Adirondack mountains stood out as a considerable obstacle in the path of the moving ice, and the tendency was for the current to divide into two portions, one of which passed southwestward up the low, broad St Lawrence valley, and the other due southward through the deep, narrow Champlain valley. As the ice kept crowding from the rear, part of the St Lawrence ice lobe pushed into the Ontario basin, while another portion pushed its way up the broad, low Black river valley and finally into the Mohawk valley. At the same time the Champlain ice lobe found its way into the upper Hudson valley, and sent a branch lobe up the broad, low Mohawk valley. The two Mohawk lobes, the one from the west and the other from the east, met in the Mohawk valley not far from Little Falls. As the ice sheet continued to push southward, all the lowlands of northern New York were filled, a tongue or lobe was sent down the Hudson valley, and finally the whole State, except the southern border of Long Island, was buried under the ice. The general direction of ice movement at this time of greatest ice extent was southward to southwestward with perhaps some undercurrents determined by the larger topographic features. Thus we learn that the major relief features of the State very largely determined the direction of ice currents, except at the time of maximum glaciation when only the undercurrents were controlled.

These ideas are abundantly borne out by the character and distribution of the glacial striae and boulders over the State. Central

New York is literally strewn with thousands of glacial boulders or erratics which were transported from the Adirondacks by the ice, and similar boulders are occasionally found as far south as Binghamton or well down the Hudson valley. Evidences of glaciation also occur high up in the Adirondacks and the Catskills, so that the greatest depth of ice over New York State could not have been less than several thousand feet. In fact, we have every reason to believe that the Adirondacks, if not the Catskills, were completely buried. The reader may wonder how an ice sheet a mile thick in northern New York could have thinned out to disappearance at or near the southern border of the State, but observations on existing glaciers show that it is quite the habit of extensive ice bodies to thin out very rapidly near the margins, thus producing steep slopes along the ice fronts.

Successive ice invasions. The front of the great ice sheet, like that of ordinary valley glaciers, must have shown many advances and retreats. In the northern Mississippi valley, however, we have positive proof for several (perhaps five or six) important advances and retreats of the ice which gave rise to true interglacial stages. The strongest evidence is the presence of successive layers of glacial debris, a given layer often having been oxidized, eroded, and covered with vegetation before the next (overlying) layer was deposited. In drilling wells through the glacial deposits of Iowa, for example, two distinct deposits or layers of vegetation are often encountered at depths of from 100 to 200 feet. Near Toronto, Canada, plants which actually belong much farther south in a warmer climate have been found between two layers of glacial debris. Thus we know that some, at least, of the ice retreats produced interglacial stages with warmer climate and were sufficient greatly to reduce the size of the continental ice sheet or possibly to cause its entire disappearance.

In New York State no very positive evidence has as yet been found to prove truly multiple glaciation, though some phenomena as, for example, certain buried gorges, are very difficult to account for except on the basis of more than one advance and retreat of the ice. At any rate, there appears to be no good reason whatever to believe that there were more than two advances and retreats of the ice over the State, and for our purpose in considering only the general effects of glaciation we may practically disregard the problem of multiple glaciation because the final effects would have been essentially the same as a result of a single great glacial advance and retreat.

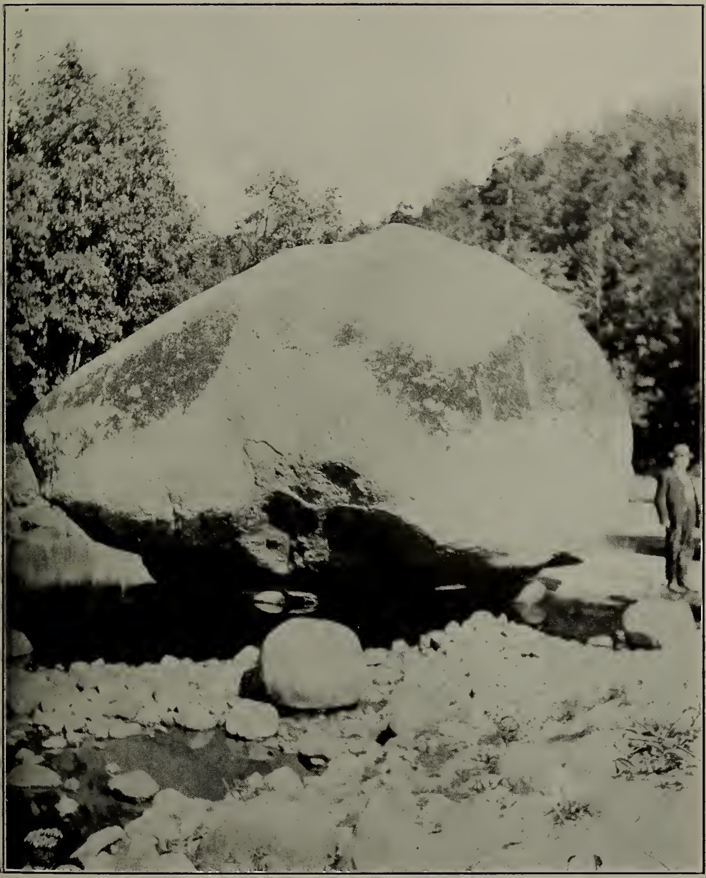
Ice erosion. Ice, like flowing water, has very little erosive effect upon rocks unless it is properly supplied with tools. When flowing ice is shod with hard rock fragments the power to erode is often pronounced because the work of abrasion is mostly accomplished by the rock fragments rather than by the soft ice itself. For instance, when the great ice lobe moved up the St Lawrence valley it was shod with many pieces of hard Precambric rocks, and the effects of erosion are remarkably well shown in the Thousand Islands region. Thus, about two miles due south of Clayton the writer has seen a succession of great grooves, covering an area of several acres, and cut into the hard, fresh Potsdam sandstone on top of a low hill. A little search will reveal polished and scratched or grooved rock surfaces in almost any part of the State. Granite ledges in the Adirondacks are often glaciated, and the freshness and hardness of the surface rock proves that the ice eroded all the deep preglacial soil as well as the zone of rotten rock, and an unknown amount of live or fresh rock.

In former years a very great erosive power was ascribed to flowing ice, but today some glacialists consider ice erosion to be almost negligible, while many others maintain that, under favorable conditions, flowing ice has a very considerable erosive effect. During the very long preglacial time, rock decomposition must have progressed so far that rotten rock, including soils, had accumulated to considerable depths, as today in the southern states. Such soils are called "residual" because they are derived by the decomposition of the very rocks on which they rest. But now one rarely ever sees rotten rock or soil in its original place in New York because such materials were nearly all scoured off by the passage of the great ice sheet, mixed with other soils and ground up rock fragments and deposited elsewhere. Such are called transported soils. Along the southern side of the State, where the erosive power of the ice was least, rotten rock is not so uncommonly seen.

Ice, shod with hard rock fragments and flowing through a deep, comparatively narrow valley of soft rock, is especially powerful as an erosive agent because the abrasive tools are supplied; the work to be done is easy; and the increased depth of the ice where crowded into a deep, narrow valley causes greater pressure on the bottom and sides of the valley. Many of the valleys of northern New York were thus very favorably situated for ice erosion, as for example, the Champlain, St Lawrence, Black river, and Finger lakes valleys, as well as many of the nearly north-south valleys of the Adirondacks. The writer has made a special study of ice erosion in the Black river valley, and figure 35 is a structure section across the valley showing the rock terraces and the relations of the various rock formations. The high, steep, terrace fronts are certainly young topographic features which could not have been present at the close of the long preglacial erosion period, nor could they have been formed since the Ice age because glacial deposits, even near the valley bottom, have not yet been removed. There is still the possibility that glacial waters may have done the work, but there is no evidence for such vigorous water action especially on the higher part of the Trenton limestone terrace where records would surely be left. On the contrary, there are glaciated rock surfaces and also glacial deposits (kames) on the great limestone terrace and near the base of the steep front of the shale terrace, so that the work could not have been done by glacial waters before the ice retreat. Evidently, we have here a fine example of ice erosion, and before the Ice age the limestones and shales extended somewhat farther eastward than they now do. The conditions for ice erosion were here unusually favorable because the ice, in its great sweep around the Adirondacks, was shod with many fragments of very hard rocks and entered the deep Black river valley striking with greatest force against the soft sedimentary rocks of the west side of the valley. As the figure clearly shows, the very soft shales were worn back more than the harder limestones, while the very hard Precambric rocks were very little affected. This is perhaps the best example of ice erosion in northern New York, and even here we must admit that only soft rocks were much eroded and that the great preglacial Black river valley was comparatively little modified. If soft shales had made up the valley bottom, ice erosion would have caused considerable deepening as was, no doubt, the case in the valleys of the Finger lakes region.

Most of the Adirondack mountain peaks, especially the more isolated ones, were thoroughly scraped off and rounded down to the very live or fresh rock (see upper view, plate 17), while the favorably situated valleys were vigorously glaciated by the removal of all the rotten and at least some of the fresh rock, especially when this latter was the comparatively soft Grenville limestone. Such phenomena are particularly well exhibited in Warren county (see figure 13) where the landscape is characterized by many great, glaciated rock domes which rise above the valleys of weak Grenville. In a few cases where the ice moved directly across deep valleys, like that between Lake George village and Warrensburg, the rotten rock to great depth may still be seen in its original place.

Plate 40



A glacial boulder or " erratic " of Precambric syenite in the bed of Black river, 2 miles northeast of Boonville, Oneida county. The boulder is 27 feet across and 17 feet high and rests upon Black River limestone. It has been transported some miles at least.

Photo by W. J. Miller

Plate 41

Drumlins in Wayne county, 3 miles north of Walworth. Looking east of south.

From N. Y. State Mus. Bul. 111, pl. 25

In conclusion we may say that while many comparatively small, local features were produced by ice erosion, the major topographic features of the State were practically unaffected by ice erosion due to the passage of the great ice sheet.

Ice deposits. The vast amount of debris transported by the great ice sheet was carried either on its surface, or frozen within it, or pushed along under it. It was very heterogeneous material ranging from the finest clay through sand and gravel, to boulders of many tons weight. The deposition of these materials, as we now see them, took place during both the advance and retreat of the ice, but chiefly during its retreat. Most of the deposits made during the ice advance were obliterated by ice erosion, while those formed during the ice retreat have been left intact except for the small amount of postglacial erosion. The general term applied to all deposits of glacial origin is "drift," this term having been given at the time when they were regarded as flood deposits. Drift deposits cover practically all of New York State except where bare rock is actually exposed, and its thickness is very variable, ranging from nothing to several hundred feet.

The ice sheet could advance only when the rate of motion was greater than the rate of melting of the ice front and vice versa in the case of retreat. Thus it is true, though seemingly paradoxical, to assert that the ice was constantly flowing southward even while the ice front was retreating northward. Whenever, during the great general retreat, the ice front remained stationary because the forward motion of the ice was just counterbalanced by the melting, all the ice reaching the margin of the glacier dropped its load to build up a *terminal moraine*. Such a moraine is a more or less distinct range of low hills and depressions consisting of very heterogeneous and generally unstratified debris, though at times waters emerging from the ice caused stratification. The depressions are usually called *kettle holes*. The so-called great terminal moraine marks the southernmost limit of the ice sheet, and is wonderfully well shown by the ridge of low irregular hills extending the whole length of Long Island (see plate 12). It is also clearly traceable across northern New Jersey and Pennsylvania and passes through southern Cattaraugus county in New York. Terminal moraines farther northward are generally not so long nor sharply defined, the one of perhaps most prominence having been traced from Herkimer through Oriskany Falls, Cortland, Watkins, Bath, Portageville, Dayton, and Jamestown. Moraines, either terminal or lateral, are often locally very prominently developed.

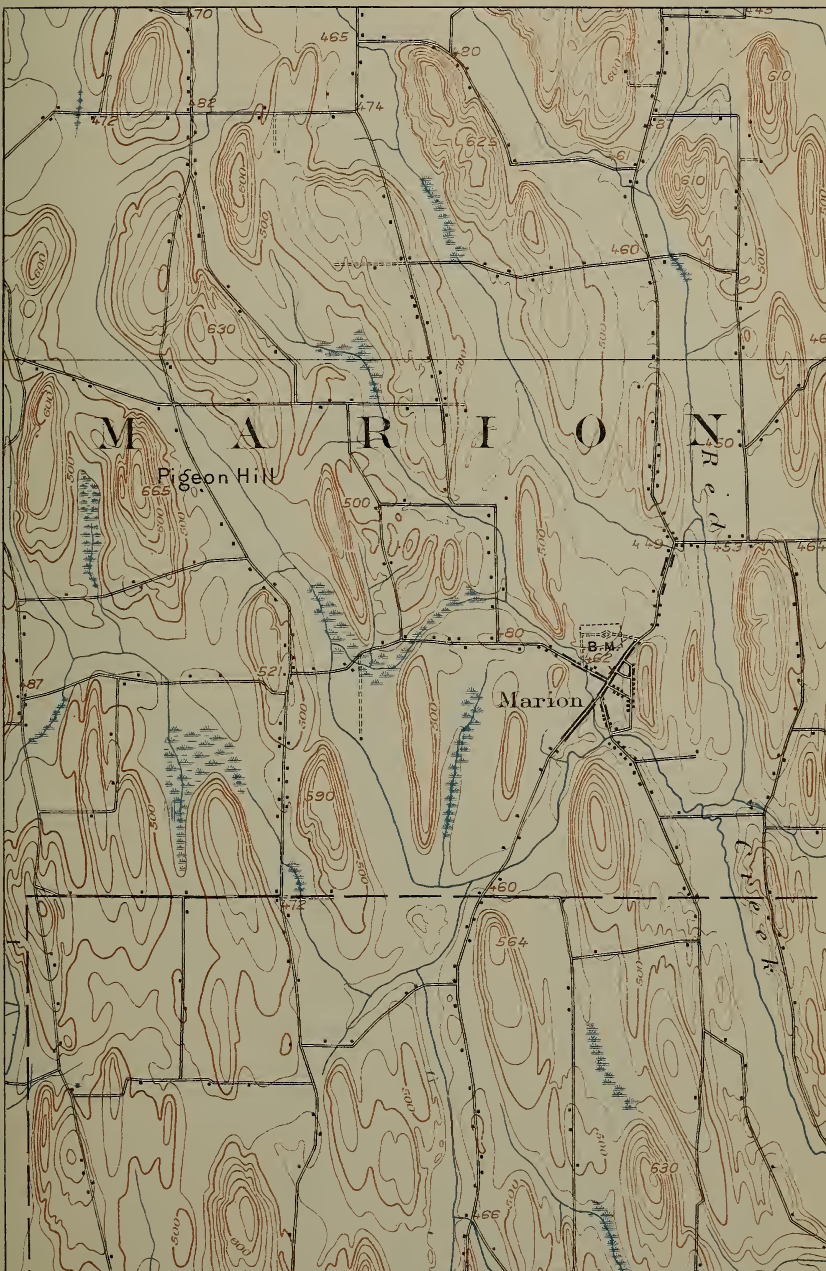
When the ice front paused for a considerable time upon a rather flat surface, the debris-laden streams emerging from the ice formed what is called an *overwash plain* by depositing layers of sediment over the flat surface. The finest illustration of such an overwash plain in the State is all of that part of Long island lying just south of the great terminal moraine, and known as the Jamaica plain toward the east (see plate 12).

When the ice front extended across a more rugged country, with valleys sloping away from the ice, the large glacial streams, heavy laden with debris, caused more or less deposition of materials on the valley bottoms often for many miles beyond the ice front. Such deposits, known as *valley trains,* are especially well developed along most of the large south-flowing tributaries of the upper Susquehanna river in the Southwestern plateau province.

Glacial boulders, or erratics, have already been referred to; they are simply blocks of rock or boulders from the top of the ice or within it which have been left strewn over the country as a result of the melting of the ice. They vary in size from small pebbles to those of many tons weight (see plate 40), and are naturally most commonly derived from the harder and more resistant rock formations. Thus erratics from the Adirondacks are very numerous in east-central New York, some having even been transported to the southern border of the State. Erratics are often found high up on the mountains, and sometimes they have been left stranded in remarkably balanced positions.

A very extensive glacial deposit, called the *ground moraine,* is simply the heterogeneous, typically unstratified, debris from the bottom of the ice which was deposited, sometimes during the ice advance, but most often during its melting and retreat. When it is mostly very fine material with pebbles or boulders scattered through its mass, it is known as *till* or *boulder clay.* The pebbles or boulders of the till are commonly faceted and striated as a result of having been rubbed against underlying rock formations.

Another type of glacial deposit of unusual interest is the *drumlin* which is, in reality, only a special form of ground moraine material or till. The typical drumlins of New York State are low, rounded mounds of till with elliptical bases and steeper slopes on the north sides and with long axes parallel to the direction of ice movement (see plate 42). In height they rarely exceed 200 feet, being most often less than 100 feet. The origin of the drumlins has not yet been satisfactorily determined, though it is known that they formed near the margin of the ice either by the erosion of an earlier drift



A topographic map illustrating that part of the Ontario plain which is studded with low, elliptical-shaped hills (drumlins) of glacial origin. Practically every hill seen from the train window between Syracuse and Rochester is a drumlin. From the Palmyra (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

Plate 43

Typical glacial topography as seen near West Junius, Ontario county. The low, irregular hills all consist of stratified glacial debris and are known as "kames."

From Annual Rep't N. Y. State Geol., 1894, pl. 8, facing p. 80

layer, or by accumulation beneath the ice under peculiarly favorable conditions, as perhaps along longitudinal crevasses or fissures. One of the finest and most extensive exhibitions of drumlins in the world is the region of western New York from Oswego and Syracuse to west of Rochester. Thousands of drumlins there rise above the general level of the Ontario plain, the New York Central Railroad, from Syracuse to Rochester, passing through the very midst of them.

Another type of glacial deposit in the low hill or hillock form is the *kame* which, in contrast with the drumlin, always consists of stratified drift. Kames are seldom as much as 200 feet high, and typically they have rounded bases though frequently they are very irregular in shape. At times they exist as isolated masses or hills or in small groups, while often they are associated with the unstratified deposits of the moraines. When grouped, deep depressions occur between the hills to form what is called the knob and kettle structure. Kames were formed at or near the margin of the retreating ice, and so are found in all parts of the State. They most generally occur in valley bottoms, but sometimes on hillsides or even hilltops. They are especially common along the line of the great terminal moraine (for example, on Long island), and also along the line of the important terminal moraine already described from central to western New York. For example, in the vicinity of Oriskany Falls kames are so numerous as to form a striking feature of the landscape in the Oriskany valley. They were formed as deposits by debris-laden streams emerging from the margin of the ice, the water sometimes having risen like great fountains because of pressure. Such deposits are now actually in process of formation along the edge of the great Malaspina glacier of Alaska.

During the retreat of the ice, glacial lakes were numerous, especially after the ice front had passed north of the Susquehanna-Allegany divide because the north-sloping valleys were dammed by the ice thus ponding the waters in the valleys. Some materials were directly deposited from the glacier in those lakes, but more was brought in by debris-laden streams flowing from the land already freed from the ice. Such glacial lakes and their deposits are common and of unusual interest, but they will be described under a subsequent heading.

In conclusion we may say that the deposition of glacial materials, like glacial erosion, has not changed the major topographic features of the State. The general tendency of ice deposits has been to fill or partially fill depressions and thus to diminish the ruggedness of the topography.

Great Lakes history. The Great Lakes certainly did not exist before the Ice age, but instead the depressions in that region were occupied by stream channels. During the very long erosion period (already discussed) from the Paleozoic to the Cenozoic, no lakes, except possibly a few very small ones due to landslides, beaver dams, etc., could have existed. Compared with such an immense length of time lakes are, at most, only ephemeral features of the earth's surface because they are soon destroyed either by being filled with sediments, or by having their outlets cut down, or both. Since the Great Lakes are of postglacial origin it is, then, proper to ask how they came into existence. During preglacial time, as we have learned, broad valleys were cut out along belts of weak rock in the Great Lakes region, and these old valleys, to a considerable extent at least, account for the present depressions, but not for the closed lake basins. This idea of preglacial stream valleys is not at all opposed by the fact that some of the lake bottoms are now well below sea level because there has been a notable subsidence of the region since preglacial time. The surface of Lake Erie is 573 feet and its deepest point 369 feet above sea level, while the surface of Lake Ontario is 247 feet above and its deepest point is 491 feet below sea level. The greatest depth (738 feet) of Lake Ontario is well toward the east end and not far from the south shore, and if we consider this deep place as due to preglacial erosion, we ought to find an outlet channel. But no such outlet channel exists because the whole eastern end, at least, of the lake is certainly rock-rimmed. As Tarr has said: "There could hardly be a valley over 700 feet deep and broad enough to form the continuation of the preglacial Ontario valley, which is so completely obscured by drift that not the least trace of it has been found on the surface."[1] To assume that this deep part of the basin was produced by warping of the land is not borne out by examining the exposed strata on all sides. It therefore seems quite certain that the preglacial Ontario depression was here considerably deepened by ice erosion. The conditions were very favorable for such erosion because the rocks were chiefly soft Ordovicic shales; because the ice flowed through a deep preglacial valley; and because there was unusual crowding of ice into this valley due to the pronounced deflection of a great ice current around the Adirondacks on the west side. Strong arguments might be adduced to show that by ice erosion, portions, at least, of all the

[1] Tarr's Physical Geography of New York State, p. 235.

lake basins were appreciably deepened. Even so, however, we have not yet accounted for the present closed basins. In the writer's opinion the two most important phenomena which have contributed to the formation of the closed basins of the Great Lakes are the great drift accumulations along the south side and the tilting of the land downward on the north side of this region. The deep drift deposits must certainly have been very effective in damming up the south or southwesterly-flowing preglacial streams of the region. For example, the deep channel of the so-called Dundas

FIG. 30 The first stage in the formation of the Great Lakes, when most of the region was still buried under the ice.

After Taylor & Leverett

river (see figure 27) has been drift-filled as proved by many well borings, and a distinct moraine extends around the southern half of Lake Michigan. The great dumping ground of ice-transported materials from the north was in general along the southern side of the Great Lakes and southward. Late in the Ice age the land on the northern side of the Great Lakes region was lower than it is today as proved by the tilted character of certain well-known beaches of extinct glacial lakes (see below). Such a differential tilting or warping of the land must have helped to form the closed basins by tending to stop the southward or southwestward drainage from the region. To summarize, we may say that the present Great Lakes basins are due to a combination of factors, the more important of which were: the formation of preglacial valleys by stream erosion; a more or less deepening of these valleys by ice erosion; the great accumulation of glacial debris along the southern side of the Great Lakes region; and the tilting of the land downward toward the north.

We are now ready to trace out the principal stages in the history of the Great Lakes during the final retreat of the ice sheet. When the ice front had receded far enough northward to uncover the western end of Lake Superior, the southern end of Lake Michigan, and an area west of the present end of Lake Erie, small lakes were formed against the ice walls (see figure 30). One of these has been called Lake Duluth which drained southward into the Mississippi; the second Lake Chicago which drained past Chicago through the Illinois river and into the Mississippi; and the third Lake Maumee which drained southwestward past Fort Wayne through the Wabash river and into the Ohio and Mississippi.

At a still later stage the conditions shown on the map (figure 31) existed. Lake Chicago was then much larger, and Lake Maumee

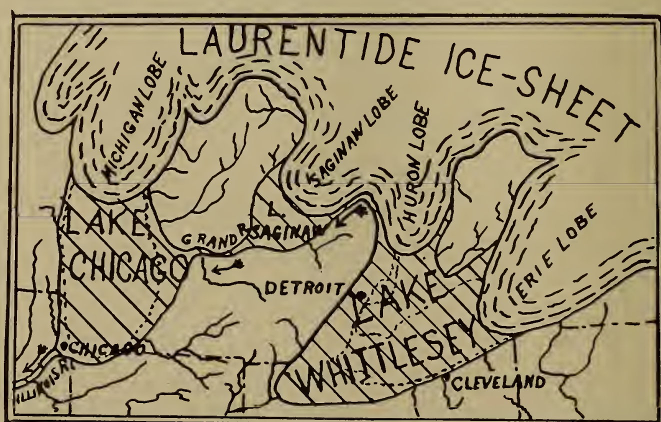


FIG. 31 A later stage of Great Lakes history, showing how the eastern and western ice margin lakes combined with outlet past Chicago.

After Taylor

had expanded into the extensive Lake Whittlesey which covered nearly all of Lake Erie as well as the immediately surrounding country. Lake Whittlesey was at a lower level than the former Maumee and the outlet past Fort Wayne ceased, but the drainage from Whittlesey was westward by a large river flowing through small Lake Saginaw and into Lake Chicago, which latter still emptied through the Illinois river.

At a still later stage (figure 32) Lake Saginaw merged with the waters of the Erie basin to form the large Lake Warren which extended along the ice front eastward nearly to central New York. As the map clearly shows, the Finger lakes basins of New York were then occupied by Warren waters, while Niagara Falls were not then in existence because that region was also covered by Lake Warren. Lake Warren continued to discharge westward into Lake Chicago and the Mississippi river until a very late stage, when the waters had worked their way along the border of the Ontario ice

FIG. 32 Glacial Lake Warren. At this stage the discharge of the lake was still westward to Lake Chicago and the Mississippi river, while the eastern end of the lake covered most of the Finger Lakes region of New York.

Modified from Taylor & Leverett, U. S. G. S.

lobe into the Mohawk valley which was then occupied by a large glacial lake (held up by the Ontario ice lobe on the west and the Champlain-Hudson lobe on the east) and thence into the Hudson valley. Thus, for the first time, the Great Lakes drainage passed eastward into the Atlantic ocean. This great volume of water draining eastward was often in the form of distinct streams with the ice front for north wall and the high land of the Helderberg escarpment for wall on the south. Many of these glacial stream channels, which are still plainly visible, have been studied and mapped by Professor Fairchild.

By successive stages, due to a complete removal of ice from central New York and a draining of the glacial lake in the Mohawk valley, the waters dropped to below Warren level until Lake Iroquois was formed (see figure 33). The old beach line of this lake is still plainly visible in New York and with some slight interruptions has been traced from near the mouth of Niagara river to just north of Rochester, past Syracuse, along the south, east, and north sides of Oneida lake, and thence along the western base of the Tug Hill plateau to near Watertown. The well-known ridge road between Niagara river and Rochester is built on the old

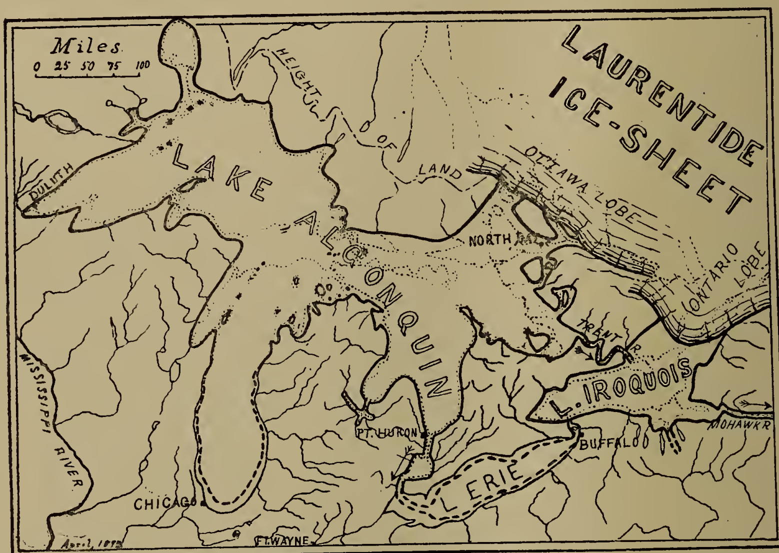


FIG. 33 The Algonquin-Iroquois stage of Great Lakes history when the ice had retreated far enough to open the outlet through the Mohawk valley.

After Taylor

Iroquois beach deposit. Lake Iroquois covered somewhat more than the present area of Lake Ontario, and the distinctly lower water level here than in the Erie basin allowed the modern Niagara river to begin its history by flowing northward over the limestone plain near Buffalo. Meantime the waters of the upper lake basins had merged to form Lake Algonquin which at first probably discharged past Detroit through the Erie basin and into Lake Iroquois by way of Niagara river. Later, however, when the ice had withdrawn a little farther northward, a lower outlet was opened through the Trent river by which Lake Algonquin drained into Lake

Iroquois. We know that the old Trent river channel is now higher than the Detroit outlet, but some of the proofs for the existence of the Trent outlet are as follows: the presence there of a large, distinct river channel; the convergence of the beaches toward that channel; and the fact that the land was then considerably lower on the north or northeast side of Lakes Ontario and Erie than on the south side. For example, in following the old Iroquois beach we find that it now gradually rises to higher levels until, even at Watertown, it is several hundred feet higher than near the mouth of the Niagara river. This tilting of the beach has been due to raising of the land since the lake existed, and it is evident therefore that during the Algonquin-Iroquois stage the Trent river channel was lower than that past Detroit. During this Lake Iroquois stage the waters of all the Great Lakes region discharged through the Mohawk-Hudson valleys, and the volume of water which flowed past Rome, Utica, and across the preglacial divide at Little Falls must have been as great, if not greater, than that which now goes over Niagara Falls. Much of the gorge cutting at Little Falls was accomplished by this great volume of water. The St Lawrence valley was still buried under the ice.

Still later the ice withdrew enough to allow the Algonquin-Iroquois waters to discharge along the northern base of the Adirondacks and into what appears to have been ice-ponded waters in the Champlain basin, and thence southward into the Hudson valley. The Mohawk river outlet was thus abandoned.

Finally the ice retreated far enough to free the St Lawrence valley when the waters of the Great Lakes region dropped to a still lower level, bringing about the Nipissing Great Lakes stage (see figure 34). The Nipissing lakes found a low outlet through the Ottawa river (then free from ice) and into the Champlain arm of the sea. Postglacial warping of the land brought the Great Lakes region into the present condition, but this, and the Champlain subsidence, being really postglacial features will be described toward the end of the chapter.

Other existing lakes and their origin. Counting all, from the smallest to the largest, there are within the borders of New York State thousands of lakes, which constitute one of the most striking differences between the geography of the present and that of preglacial time. These lakes are widely scattered over the State though there are three general regions worthy of particular mention as follows: the Finger lakes region of western New York; the Adirondack mountains; and the southeastern portion of the State.

The linear type of lake is by far the most common, this being preeminently true of the Finger lakes and to a large extent of the Adirondacks. It is well known that most of the larger lakes, especially those of the linear type, occupy portions of preglacial stream channels. All the existing lakes are due, either directly or indirectly, to glacial action, and among the ways by which such bodies of water were formed are these: by building dams of glacial drift across old river channels; by ice erosion; and by the filling of the numerous depressions which were formed by irregular deposition of the drift (kettle holes, etc.). Hundreds of small lakes, often

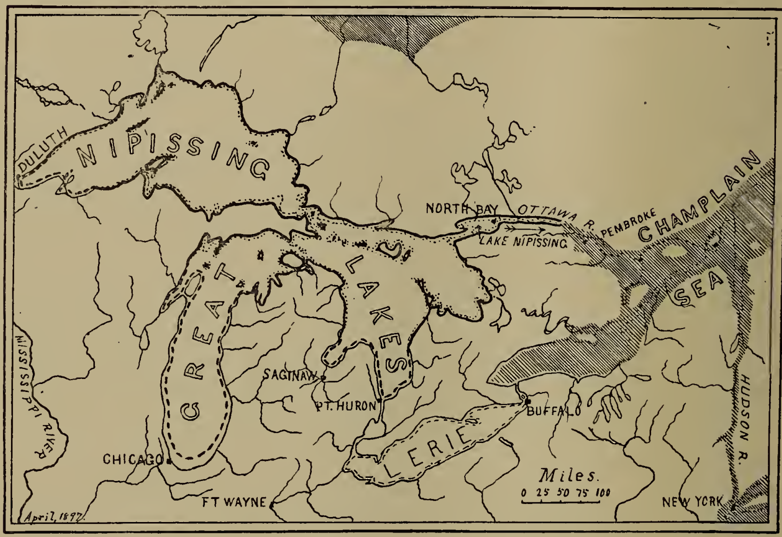


FIG. 34 The time of the Nipissing Great Lakes and Champlain submergence. The shaded area on the east was covered by sea water.

After Taylor

not more than mere ponds in size, belong to the last named type, while most of the large lakes are due chiefly to the existence of drift dams.

Much has been written concerning the origin of the Finger lakes, and only the briefest summary will here be given. All are agreed that the lakes of this remarkable group occupy preglacial valleys, most of which, at least, contained north-flowing streams. These lakes have dams of glacial drift across their lower (north) ends, and the dams have largely contributed to the formation of the lakes, being in some cases perhaps the sole cause of the lakes. In the cases of the two largest lakes, Seneca and Cayuga, there is, however, strong evidence that the preglacial channels were notably deepened by ice erosion.[1] As Professor Tarr says: "They offered broad channel ways, along which the ice streams moved much more easily than upon the neighboring irregular hilltops. Not only was the movement more rapid, but the depth of ice was greater. The position of the rocks, dipping southward, and the nature of the friable shales conspired toward rapid erosion; and so these north and south preglacial valleys were markedly deepened. Evidence of this comes from the side streams. The rock bottoms of the preglacial valleys of these tributary streams are not now below the level of the lake water in the southern part of the valley (Cayuga). If all the drift could be removed and the streams be allowed to flow along the line of the course of the preglacial valleys and enter the valley of Lake Cayuga as it now stands, excepting that it be robbed of water, they would tumble between 300 and 400 feet in a distance of about a mile, commencing their descent near the present lake margin, a most unnatural condition for mature tributaries near their mouth."[2] Thus it appears quite certain that the preglacial Cayuga and Seneca valleys, at least, were notably deepened by ice erosion below the level of the mouths of the preglacial tributary streams.

Most of the numerous Adirondack lakes have certainly been formed by irregular damming of preglacial valleys by glacial drift. It is quite the rule to find the outlets of these lakes flowing through such loose materials. By ice erosion many of the favorably situated valleys were no doubt somewhat modified, but up to the present time we have no good example of a lake basin produced by that agency. The hard Precambric rocks were not so easily eroded by the ice. Attention is called to the prominent lake belt in the middle of the Adirondack province, and running in a north-northeast by south-southwest direction. This belt comprises many well-known lakes as Placid, Saranac, Tupper, Long, Blue Mountain, Big Moose, and Fulton Chain lakes. Sometimes small lakes or ponds are situated well toward mountain tops because of favorably located drift deposits. A good example of such lake lies at an altitude of 2620 feet, and well toward the top of Crane mountain in Warren county.

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[1] The surfaces of Seneca and Cayuga lakes are respectively 444 and 381 feet above sea level, while their deepest places are respectively 186 and 119 feet below sea level.

[2] Tarr's Physical Geography of New York State, p. 181–82.

Many of the existing Adirondack lakes were formerly of larger extent as proved by delta deposits above the present lake levels. Two lakes of this class recently coming under the writer's observation are Schroon lake in Warren-Essex counties, and Piseco lake in Hamilton county. The water of Schroon lake was once fully 70 feet higher when it extended some eight or ten miles farther up the Schroon river, with a branch reaching over the area of the present Paradox lake, and also for some six or eight miles farther southward to cover all the lowland around Chestertown, and with a prominent branch extending over the area of the present Brant lake. Piseco lake was at one time clearly twenty feet higher, and then extended several miles farther northward.

The valley of Lake Champlain was favorably situated for ice erosion, and it bears evidence of having been vigorously glaciated though it has not been proved that the existing closed basin is chiefly due to ice erosion. At the close of the Ice age, tide water entered the valley. The present lake basin is due principally to a combination of late elevation of the land, with greater uplift on the north; heavy glacial accumulations toward the north; and possibly some deepening as a result of ice erosion.

Lake George is justly famous because, from the standpoint of length and depth in proportion to width, no other lake in the State occupies such a remarkable depression. This depression has been determined by ordinary erosion along lines of prominent faults. There was a preglacial divide where the "Narrows" are now located, and this divide appears to have been considerably lowered by ice erosion when part of the Champlain ice lobe plowed its way through the deep, narrow valley. The waters are now held in by glacial deposits at each end.

In southeastern New York, from the Connecticut state line westward to the southern Catskills in Sullivan county, there are many lakes, though all are comparatively small. With few exceptions these lakes appear to be of the usual drift dam type. Greenwood lake, at an altitude of 621 feet and passing from Orange county across the state line into New Jersey, is the largest in this part of the State. Three small lakes near the summit of Shawangunk mountain, and close to its eastern edge, deserving special mention are: Mohonk, Minnewaska, and Awosting. Mohonk lake, which is so widely known both because of its remarkable situation and as a place where so many peace conferences have been held, may be taken as the type of the three. The altitude of this lake is more than 1200 feet or about 1000 feet above the base of the mountain ridge on which it is located. It is almost completely surrounded by walls of hard Shawangunk conglomerate, while the lake basin itself is in the soft underlying Ordovicic shales. This lake does not appear to owe its origin to a dam of glacial drift, but rather to ice erosion in the soft shales at a place where they had already been exposed to view before the oncoming of the ice. Such patches of shale occur at several places on the mountain.

Near the very western end of the State lies another lake remarkably situated. This is Lake Chautauqua, famous as the great center of Chautauqua assemblies. The altitude of the lake is 1338 feet, and its northern end is near the edge of the steep front of the Southwestern plateau province where it overlooks the low Erie plain. The drainage is southward into the Allegheny river, but the narrow place near the middle of the lake strongly suggests a preglacial divide there. As Tarr says: "If this view be true, Chautauqua lake is made up of parts of two valleys, one north-sloping, the other south-sloping, and each dammed by heavy morainic accumulations." [1]

Extinct glacial lakes. Hundreds of extinct glacial lakes are known to be scattered over the State. Some of these existed only during the time of the ice retreat, while others persisted for a greater or lesser length of time after the Ice age. Lakes Warren, Iroquois etc., already described, were fine examples of the first type. North-sloping valleys were particularly favorable for the development of glacial lakes during the retreat of the ice because the ice front always acted as a dam across such valleys, thus allowing the waters to become ponded. When the ice front stood across the northern ends of the Finger Lakes valleys, the waters in those valleys were ponded at much higher levels than they now are, and the ancient water levels are more or less clearly marked by the old beach lines.

Perhaps the finest example of a large, wholly extinct glacial lake is Black lake, which occupied a good portion of the Black river valley on the western side of the Adirondacks. This lake, small at first, was formed by ponding the waters in the upper Black river valley around Forestport, Oneida county, in front of the waning (northward retreating) ice lobe in the Black river valley. Its first discharge was probably southward past Remsen. Further retreat of the ice lobe permitted an enlargement of the lake to the region around Boonville, and the discharge was then southward along the channel of the present Lansing kill. The deep, narrow gorge a

[1] Tarr's Physical Geography of New York State, p. 205.

few miles south of Boonville, along this stream, was mostly cut by the fairly large stream which drained the glacial lake at this stage. The southward discharge through this channel appears to have been into the Lansing Kill lake where a delta deposit was formed a few miles north of Rome and now the site of the Delta reservoir. Lansing Kill lake in turn drained through the Mohawk Valley. Still further retreat of the ice lobe allowed Black lake to expand greatly until it reached from the region around Forestport to north of Lowville, when it had a width of from five to ten miles. When the ice withdrew enough to permit a discharge of water around the north base of Tug hill, and into Lake Iroquois, the level of the lake rapidly fell until the ice barrier was completely removed. The former presence of this great glacial lake is conclusively shown by the extensive development of unquestioned delta deposits. Where the streams from the Adirondacks, especially the larger ones such as Black, Moose, and Independent rivers, emptied into the lake, delta deposits were rapidly built up to near the lake surface because those streams were heavily charged with debris from the newly drift-strewn mountains. These delta deposits became more or less merged, and they show a remarkable concordance of altitudes over the sand flat or sand plain country on the east side of Black river. This great delta deposit is several miles wide; very flat-topped except where trenched by postglacial streams; presents a steep front toward the river; and shows a depth of from 200 to 250 feet along the western edge. Figure 35 clearly shows the relation of the delta deposit to the old rocks of the valley.

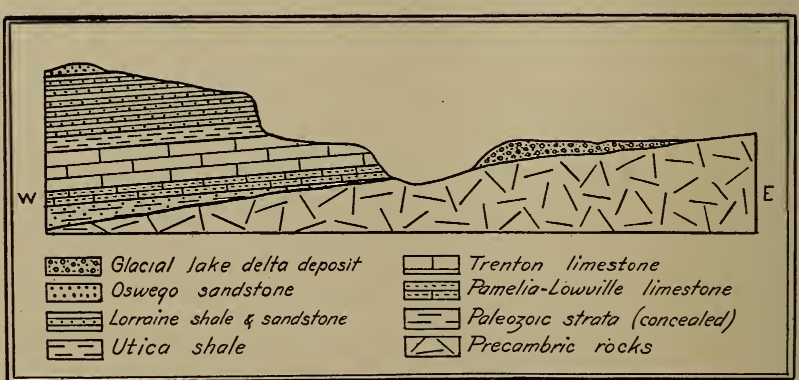


Fig. 35 East-west section across the Black river valley, 2½ miles north of Lyons Falls, showing the terraced character of the Paleozoic strata and their relations to the Precambric Adirondack rocks. On the east side, the position of the glacial lake delta deposit is shown. Length of section 12½ miles. Vertical scale greatly exaggerated.

After W. J. Miller, N. Y. State Mus. Bul. 135

In many cases where the edge of an ice lobe extended across the mouth of an east, or west, or even south-sloping valley, glacial lakes were formed. A fine example of a glacial lake (now extinct) formed in a south-sloping valley has been called glacial Lake Sacandaga which covered many square miles of the bottom of the broad, deep valley in which Johnstown, Gloversville, and Northville are located. Through this valley, which has a width of several miles and a maximum depth of over a thousand feet, the preglacial Sacandaga flowed southward into the Mohawk. During the general ice retreat, but when the Mohawk glacial lobe was still present, morainic deposits along the margin of the ice lobe formed an effective barrier across the mouth of the valley thus ponding the waters over the valley bottom and causing the Sacandaga to find an outlet northeastward over the low divide at Conklingville. The altitude of the lake corresponded approximately with the present 780 foot contour line, though it is quite certain that the land was then somewhat lower. This lake persisted for a good while after the disappearance of the ice because of the effective drift dam, and even today, in the spring of the year, a number of square miles of swamp in the lowest part of the valley are flooded. The lake was drained by cutting down the divide at Conklingville. It is interesting to note in passing that the construction of the proposed Sacandaga reservoir, by means of a dam at Conklingville, would almost exactly restore this former glacial lake.

Many other glacial lakes are known to have been formed by ponding of water alongside the waning Mohawk ice lobe. During the melting of the ice tongue from the Hudson and Champlain valleys, many small glacial lakes are also known to have been formed in the tributary valleys because of ice dams across them.

New York State fairly abounds in such extinct glacial lakes, and though comparatively few have yet been described, they are usually easily recognizable by means of the typical, flat-topped, delta deposits of crudely stratified sands, gravels and clays.

Drainage changes, gorges, and waterfalls. Along with its lakes, New York State is also famous for its numerous gorges and waterfalls, which are also largely due to the great Ice age. As a result of the very long preglacial erosion period, it is perfectly clear that typical, steep-sided, narrow gorges and true waterfalls must have been very uncommon, if present at all. Like lakes, such features are ephemeral because, under our conditions of climate, gorges soon (geologically) widen at the top and waterfalls disappear by retreat or by wearing away the hard rock over which they fall.

Drainage changes, aside from those already described in connection with the history of lakes, are also numerous in New York. It must be remembered that, with few exceptions (for example, the basins of Lakes Ontario and Erie, Niagara river, and possibly the St Lawrence river), the major drainage lines of the State were little changed during the Ice age because the principal valleys were mostly the same before and after glaciation. It is the present purpose briefly to describe only some of the most important and best known cases of stream changes due to the Ice age.[1]

From the standpoint of both geography and human history, the gorge at Little Falls is the most important in New York State (see figure 7 and plate 42 and also the description in chapter 2). Before the Ice age there was a divide, instead of the gorge, several hundred feet above the present river level, which consisted of hard Little Falls dolomite. The prominence of this rock barrier was greatly increased by the tilting of the strata due to the development of the Little Falls fault. The Mohawk river flowed eastward, and the now extinct Rome river flowed westward, from this divide (see figure 36). During the Ice age the divide was somewhat lowered

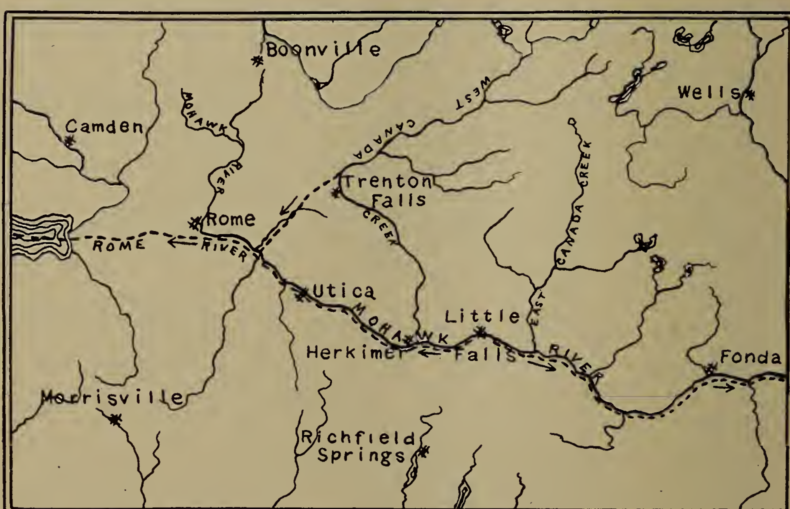


FIG. 36 Sketch map of central New York, showing the relation of preglacial to postglacial drainage. Preglacial streams shown by dotted lines only where essentially different from existing streams.

Based upon wo.k of A. P. Brigham

[1]All the drainage changes now to be described will be much better understood by consulting the large government topographic maps of the regions considered.

Plate 44

General view of the gorge at Little Falls, looking up the Mohawk river from the eastern part of the city. In the bottom of the gorge is Precambric igneous rock (syenite), while the steep hills on either side of the river are of Little Falls (Cambric) dolomite.

From N. Y. State Mus. Bul. 77, pl. 12

by ice erosion, and during the Algonquin-Iroquois stage of the Great Lakes history, we have learned that these lakes discharged through the Mohawk valley and across the Little Falls divide. It was the passage of this great volume of water over the divide which caused the cutting of most of the gorge as we now find it, except for the narrow trench in the hard, underlying Precambric rock which is no doubt due to postglacial erosion. During the Iroquois stage an arm of the lake extended along the valley from Rome to Little Falls. All the streams from north and south which entered this arm of the lake were heavily charged with debris from the newly drift-covered regions and, the current not being strong enough to carry away the debris, the valley from Rome to Little Falls was built up (aggraded) to such an extent that, after the disappearance of Lake Iroquois, the drainage from Rome was able to continue eastward. Thus we have here a very fine example of exact reversal of drainage directly due to glaciation and by this means the upper waters of the Mohawk were added to the preglacial Mohawk.

Closely associated with the above is the postglacial history of West Canada creek and the famous chasm at Trenton Falls. The preglacial West Canada creek flowed from Prospect (upper end of Trenton chasm) past Holland Patent, through the valley of the present Nine Mile creek, and into the Rome river opposite the village of Oriskany. This channel was completely blocked by glacial drift at Prospect so that the creek was forced to find a new course southward over the limestone at Trenton Falls, and thence southeastward to its present mouth at Herkimer. The gorge, between Prospect and Trenton Falls villages, is 2½ miles long and from 100 to 200 feet deep, and has been cut into the Trenton limestone by the postglacial stream. It contains five or six waterfalls ranging in height from 10 to 126 feet, the total drop of the water in the 2½ miles of the gorge being 360 feet (see plates 43 and 44).

In the southeastern Adirondacks; the upper waters of the Hudson river present some very interesting examples of drainage changes. In fact, it is not too much to say that the larger drainage features of that region have been well nigh revolutionized as a result of glaciation. The accompanying sketch map (fig. 37) gives a fair idea of the changes, but reference to the State geologic map and to the topographic maps of the region is greatly to be desired. The State geologic map shows two distinct embayments of Paleozoic rocks forming valleys which extend northward, one to Northville and the other to Corinth, and into the mass of Precambric rocks of the

Adirondacks. It is certain that these valleys contained important preglacial streams which flowed southward out of the mountains. Now, however, the Sacandaga river enters the north end of the

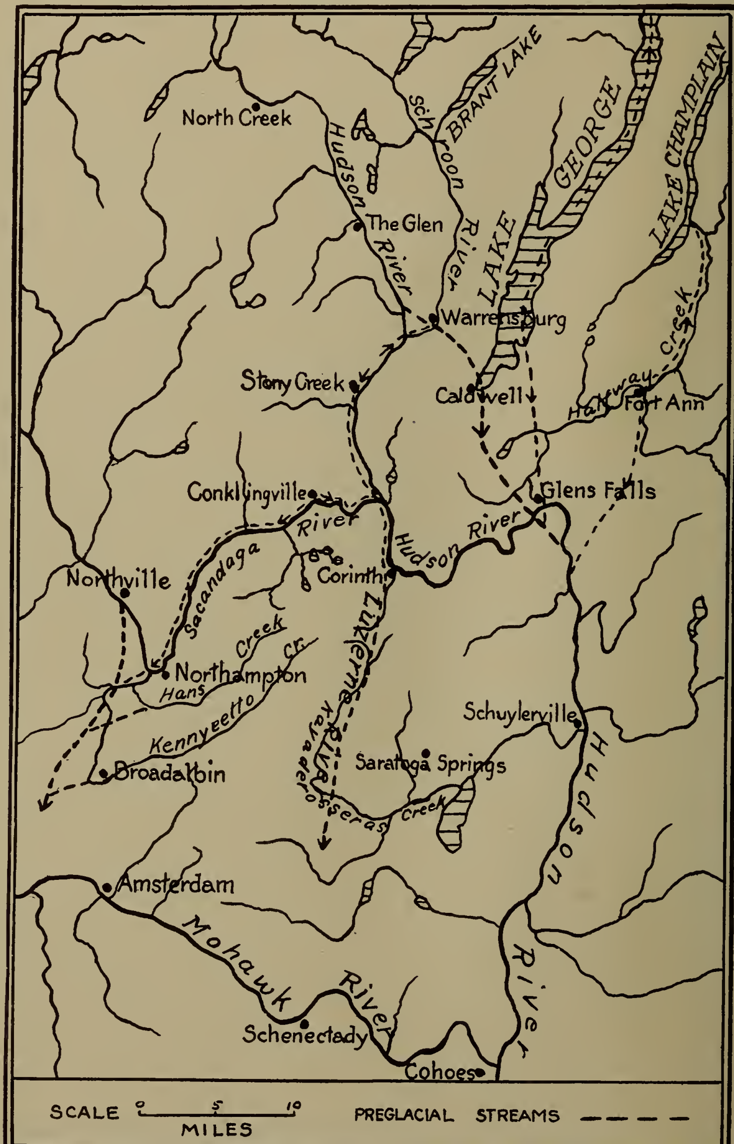


FIG. 37 Sketch map of the southeastern Adirondack region, showing the relation of the preglacial drainage to that of the present. Preglacial courses shown only where essentially different from present streams.

After W. J. Miller, Bul. Geol. Soc. Am., vol. 22

Plate 45

High Falls in the gorge at Trenton Falls, Oneida county. Both the upper and lower portions of the falls are shown, the total descent of the water being 126 feet. The rock is Trenton limestone, at its classic locality, and it abounds in early Paleozoic fossil shells. The gorge here is 200 feet deep and wholly of postglacial origin.

Photo by F. B. Guth, Utica, N. Y.

Plate 46

A nearer view of the upper portion of the High Falls, at Trenton Falls, Oneida county. The height of this fall is 50 feet.

Photo by F. B. Guth, Utica, N. Y

first named valley only to make a very sharp turn back on its course to flow across the mountains and into the Hudson at Luzerne. A preglacial divide was located at Conklingville as shown by the gorge there; the perfectly graded condition of the valley bottom westward from that place; and the flaring of the valley westward. This remarkable deflection of the river was caused by the building of a morainic blockade across the southern end of the Paleozoic rock valley from Broadalbin to Gloversville. The peculiar courses of Hans and Kennyetto creeks are thus also easily explained.

The Hudson river now flows through a gorge more than 1000 feet deep just above Stony Creek station, and thence to the north end of the Paleozoic rock valley at Corinth where it turns abruptly to the northeast to flow across the Luzerne mountain ridge. The preglacial Hudson certainly did not flow through the Stony creek gorge, but rather, where the gorge now is, there was an important divide. Among other proofs for this former divide are: the deep, narrow gorge of recent origin; the flaring of the valley both northward and southward from the gorge; and the anomalous turns of both the Hudson and Schroon rivers toward the southwest through a highland region of hard rock, instead of southeastward across the much lower land between Warrensburg and Lake George. The most probable preglacial channel was past Warrensburg, Caldwell, and Glens Falls as shown on the map. The now extinct Luzerne river started on the Stony creek divide, and flowed southward past Corinth and thence through the Paleozoic rock valley to the west of Saratoga Springs. The cause of the passage of the Hudson over the Stony creek divide was partly due to a lowering of the divide by ice erosion, but mostly to the fact that during the ice retreat the ice lobe in the Lake George depression forced the Hudson river to take a more westerly course which was continued after the melting of the ice. The deflection of the river across the Luzerne mountain divide was certainly caused by heavy drift accumulations in the Paleozoic rock valley south of Corinth.

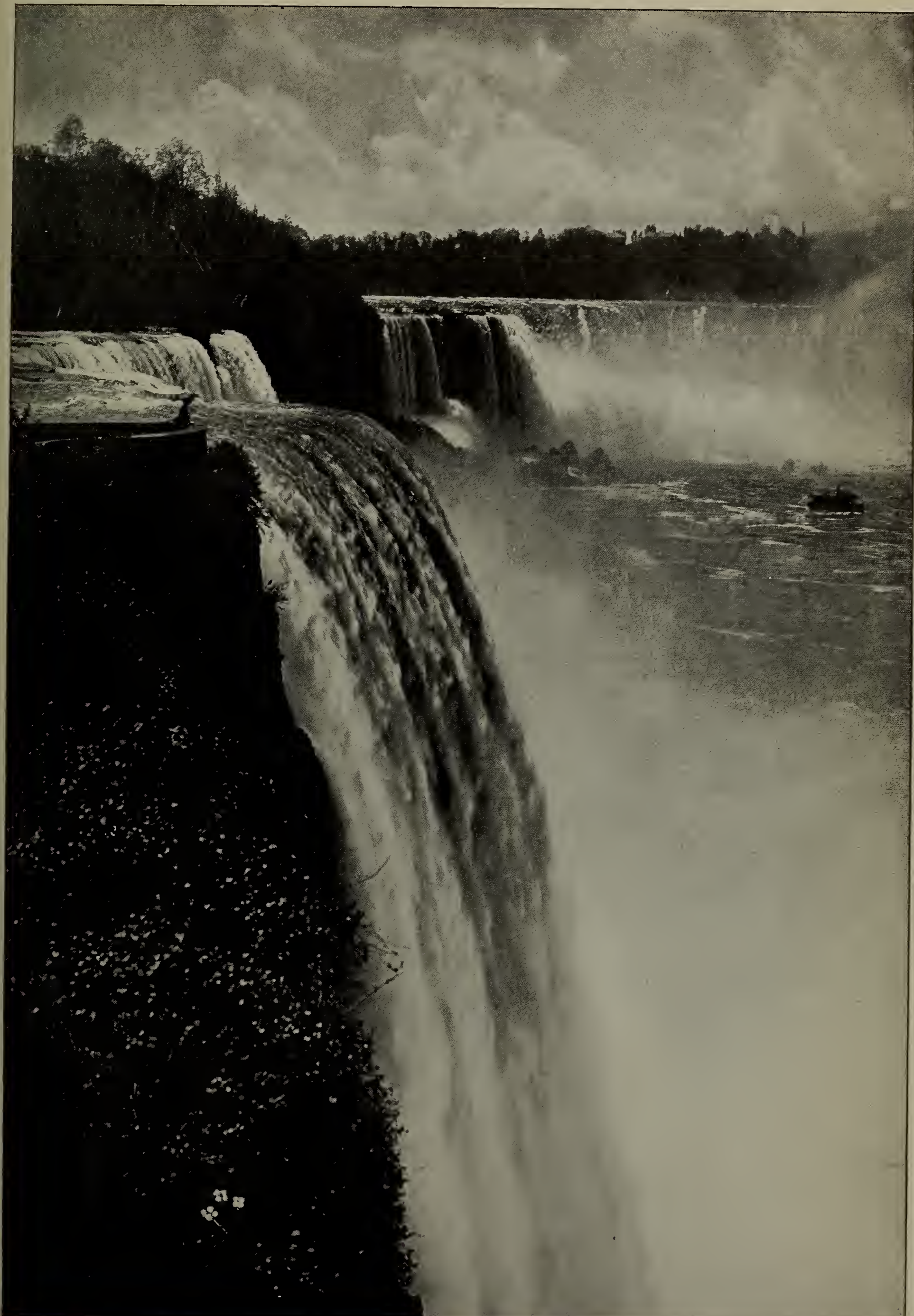
The famous Ausable chasm in Clinton county is a fine illustration of a deep, narrow gorge cut through the Potsdam sandstone by the Ausable river since the Ice age. The river was deflected from its preglacial channel by heavy drift filling.

According to evidence recently presented by Fairchild, the lower portion of the Black river did not flow, as now, westward past Watertown and into the Ontario basin, but continued northward to northeastward into the St Lawrence valley and in perfect harmony with the rock structures and other drainage lines. The diversion from the preglacial course was due to heavy glacial accumulations between the villages of Black River and Evans Mills.

The deep, narrow gorges which have been cut through the steep eastern and northeastern fronts of the Tug Hill plateau are commonly called "gulfs." Of these the Whetstone gulf (see plate 8) is the most interesting and though little known it is one of the finest examples of its kind in the State. Its length is two miles, and for one mile it shows a depth of 300 feet. The walls are very steep-sided to nearly vertical, especially in the upper end (narrows) where there is just room enough for the swift stream at the bottom. This gulf is certainly postglacial in origin and has been cut into the soft Lorraine and Utica shales. During glacial times the shales were eroded back by the ice (see above) causing the development of the steep eastern front of Tug hill. After the ice disappeared, all east-bound streams from Tug hill, not in their preglacial channels, rushed over the steep shale front and began to erode notches into its summit. These notches were rapidly deepened in the soft shales to form the gulfs whose heads have since been cut back to their present positions.

The world famous Niagara Falls and gorge are wholly postglacial in origin. After plunging 167 feet at the falls, the river rushes for 7 miles through the gorge whose depth is between 200 and 300 feet (plates 47, 48, 49 and 50). When the glacial waters in the eastern Great Lakes region had dropped to the Iroquois level, the Niagara limestone terrace in the vicinity of Buffalo and with steep escarpment or northern front at Lewiston and Queenston, ceased to be covered by lake water, and the Niagara river came into existence by flowing northward over this limestone plain. The river first plunged over the escarpment at Lewiston and Queenston, thus inaugurating Niagara Falls there. Since that time the falls have receded the 7 miles up stream to their present position. In figure 38 we see that soft shales underlie the hard layer of Niagara limestone, and the recession of the falls has clearly been caused by the breaking off of blocks of limestone due to undermining of the soft shales. A glance at the map (plate 50) will show that the gorge development is really taking place on the Horseshoe falls side where the volume of water is much greater, and that in a short time, geologically considered, the American falls will be dry. The rocks exposed in the gorge walls are Niagara limestone, under which in regular order come Niagara (Rochester) shale, Clinton

Plate 47



General view of Niagara Falls from the American side

From N. Y. State Mus. Bul. 45 pl. 1

Plate 48

The Horseshoe falls with Goat island and the Three Sisters, as seen from the Canadian side. This view illustrates the narrowness of the gorge now forming.

From N. Y. State Mus. Bul. 45, pl. 11

Plate 49

The Whirlpool rapids and American bank of Niagara gorge, looking north. The rocks are nearly horizontal strata of Siluric age consisting of Lockport or Niagara limestone (forming uppermost cliff) followed downward by Rochester shale, Clinton limestone and shale (exposed near middle of bank), and Medina sandstone and shale. The gorge is here 250 feet deep.

From N. Y. State Mus. Bul. 45, pl. 10

Portion of the Niagara Falls (U. S. G. S.) quadrangle, showing the position of the Falls, the long, narrow gorge cut through the very level Ontario plain, the position of the Whirlpool and the "Niagara escarpment" at Queenston. Scale, about 1 mile to the inch.

shale, and Medina shale and sandstone. These formations show only a slight southward dip or tilt.

The Genesee river from its source to Portageville, Wyoming county, appears to be in a mature preglacial valley. Near Portageville, however, the river plunges into a deep, narrow, rock gorge of postglacial origin, which continues for 25 miles to Mount Morris. This gorge has been cut through soft Devonic shales and shaly sandstones, and its walls are mostly nearly vertical, often rising to heights of several hundred feet. The three noted Portage falls (see plate 51) are situated just below Portageville, the upper falls

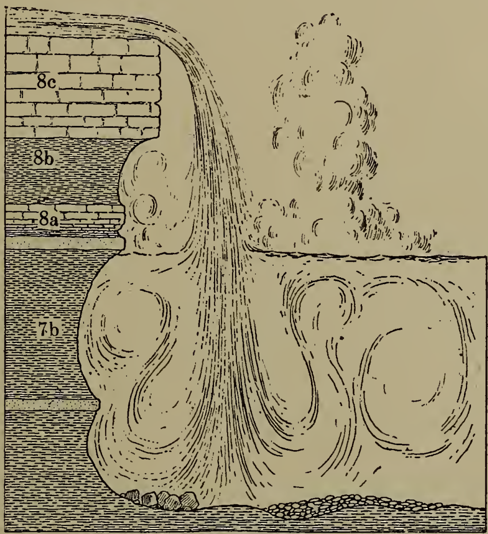


FIG. 38 Section at Niagara Falls, showing the character and position of the rock formations and the depth of water below the falls.
After Gilbert

plunging 66 feet, the middle falls 110 feet, and the lower falls 96 feet. According to Grabau, the preglacial course between Portageville and Mount Morris was farther westward along the present Oatka creek. A second postglacial gorge is entered at Rochester, and this continues for 7 miles to the mouth of the river. Here, also, are three falls, the first over Niagara limestone being 98 feet, the second over Clinton shale and limestone being 20 feet, and the third over Medina sandstone being 105 feet. The preglacial channel here was probably a little to the east and through Irondequoit bay.

In the southern Finger lakes region of south-central New York there are numerous postglacial gorges, a few of the best known ones being: Watkins and Havana glens near the southern end of Seneca lake, Taughannock gorge on the west side of Cayuga lake and in northern Tompkins county, and the gorges of Butternut (Enfield), Fall, Six Mile, and Buttermilk creeks in the vicinity of Ithaca. These gorges all contain waterfalls and have been cut into Devonic shales or sandy shales by streams which have been either partly or wholly diverted from their preglacial courses due to heavy drift filling. In some cases, as at Watkins and Taughannock, the main north-south Seneca and Cayuga valleys were scoured and somewhat deepened by ice erosion, while in all cases the tributary channels were heavily drift filled, thus accounting for the frequent postglacial diversion of these streams which were forced to cut new channels into the steep slopes facing the main valleys.

Watkins glen is several miles long, often very narrow, and with a maximum depth of over 300 feet. Taughannock gorge, which is one and a quarter miles long and with greatest depth of about 350 feet, has in it Taughannock falls whose height is 215 feet and which takes rank as the highest true waterfall in New York State (see frontispiece). Fall creek gorge, on the north side of Cornell campus, is about a mile long and with greatest depth of about 200 feet, and contains Triphammer and Ithaca falls. The Butternut creek (Enfield) gorge is two miles long and with maximum depth of over 300 feet.

In Chautauqua county there are numerous gorges or so-called gulfs which have been cut through the steep front or escarpment of the western border of the Southwestern plateau province. A fine example is the gulf south of Westfield, which is several miles long and from 300 to 400 feet deep. These are also postglacial channels which have been worn into the soft Devonic shales. The steepness of the shale escarpment here, as in the case of Tug hill, was more than likely produced by ice erosion, while the preglacial north-flowing streams had their channels partially or completely filled with glacial debris so that the streams now often flow in postglacial channels. The conditions are here very similar to those of the Finger lakes region already described.

Length of time since the Ice age. Estimates of the duration of the glacial epoch by the most able students of the subject vary from 500,000 to 1,500,000 years, these estimates being based on such criteria as amount of erosion and weathering of the earliest till sheets (in Mississippi valley), times necessary for the various

Plate 51

Middle falls and the gorge of the Genesee river just below Portageville. The falls are 110 feet high and the exposed rocks are shales and sandstones of Portage (Devonic) age. The gorge is postglacial in origin.

From N. Y. State Mus. Bul. 118, pl. 15

Plate 52

Triphammer falls and gorge at the edge of Cornell University campus, Ithaca, N. Y. The rocks are dark, thin bedded shales of Lower Portage (Devonic) age. The gorge is postglacial in origin.

From N. Y. State Mus. Bul. 19, pl. 81

advances and retreats of the ice sheets etc. Although a closer calculation is well nigh impossible because of the variability of the factors involved from time to time, it is nevertheless certain that, from the geological standpoint, the Ice age was of short duration, while, from the standpoint of known human history, it was immensely long.

Estimates of the length of time since the close of the Ice age are perhaps more satisfactory, though it must be remembered that the close of the Ice age was not at the same time for all places. The ice retreated northward very slowly and when, for example, southern New York was free from the ice, northern New York was still glaciated. The best estimates for the length of time since the

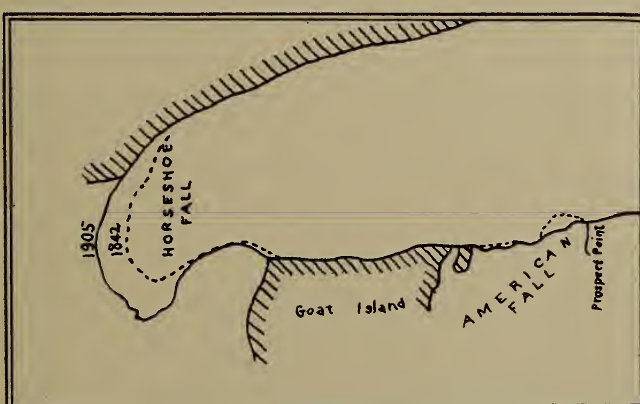


FIG. 39 Sketch map showing the relation of the crest of Niagara Falls in 1842 to that of 1905. Based upon actual surveys. The retreat of the inner portion of the Horseshoe Fall was more than 300 feet.

Modified after Gilbert, U. S. G. S. Bul. 306, p. 20

close of the Ice age in New York State are based upon the rate of recession of Niagara falls. We have learned that the Niagara river began its work about the time the glacial waters in the Erie-Ontario regions had dropped to the Iroquois level, and that the falls were first formed by the plunging of the river over the Niagara limestone escarpment at Queenston and Lewiston. Studies based upon actual surveys, drawings, daguerreotypes, photographs etc. made between the years 1842 and 1905, have shown that the Horseshoe fall had receded about 5 feet a year, while the American fall between 1827 and 1905, had receded about 3 inches a year. Thus the gorge cutting is clearly taking place on the Canadian side. The length of the gorge is 7 miles, and if we consider the rate of recession to have been always 5 feet a year, the length of time necessary to cut Niagara gorge would be something over 7000 years. But the problem is not so simple, since we know that at the time of, or shortly after, the beginning of the river, the upper lakes drained out through the Trent river, and then still later through the Ottawa river. So it is evident that, for a good part of the time since the ice retreated from the Niagara region, the volume of water passing over the falls was notably diminished, and hence the length of time for the gorge cutting increased. The best estimates for the length of time since the ice retreated from the Niagara region vary from 7000 to 50,000 years, an average being about 25,000 years. In a similar way the time based upon the recession of St Anthony's falls, Minnesota, range from about 10,000 to 16,000 years. While closer estimates are practically impossible, it is at least certain that the time since the Ice age is far less than its duration, and that, for the region of New York State, the final ice retreat occurred only a very short time ago.

When we consider the slight amount of weathering and erosion of the latest glacial drift, we are also forced to conclude that the time since the close of the Ice age in New York is to be measured only by some thousands of years. Thus kames, drumlins, extinct lake deltas, and moraines with their kettle holes have generally been very little affected by ice erosion since their formation.

Champlain subsidence and recent elevation of New York State. We have already shown that at about the beginning of the glacial epoch the region of New York State, especially along the eastern side, was much higher than it is today, positive proof for this being afforded by the submerged Hudson river channel which must have been cut when the land was higher. Toward the close of the Ice age and shortly after (Champlain epoch), we know that the land had subsided to a level even lower than that of today. It was during this period of subsidence that the lower Hudson and St Lawrence channels were submerged and the sea coast was transferred to more nearly its present position. But as the land was even lower than now, the lowlands of Long island and in the vicinity of New York City were under water and a narrow arm of the sea extended through the Hudson and Champlain valleys to join a broad arm of the sea which reached up the St Lawrence valley and even into the Ontario basin (see figure 34). This Champlain sea existed at the time of the Nipissing Great Lakes already described. Champlain sea beaches, containing marine shells and the bones of walruses and whales, have been found at altitudes of about 400 feet near the southern end of Lake Champlain, to 500 feet at its northern end, and 600 or more feet at the eastern end of Lake Ontario. In the lower Hudson river valley the deposits of this age are about 70 feet above sea level, and at Albany a little over 300 feet. The altitudes of these so-called raised beaches show how much lower the land was during the time of greatest submergence, and that the subsidence was most toward the north.

The most recent movement of the earth's crust over the area of the State was the very recent gradual elevation which expelled the Champlain sea and left the land at its present altitude. The altitudes of the raised Champlain beaches show that the greatest elevation was on the north. The warping of the Iroquois beaches already described occurred at this same time. Actual surveys during the past century have proved that the upward movement in the northern Great Lakes region is still progressing at the rate of 5 inches in 100 miles in 100 years.

APPENDIX

CONSTRUCTION AND USES OF GOVERNMENT CONTOUR MAPS

A number of plates, comprising portions of government topographic (contour) maps, have been introduced into this book for the purpose of illustrating the typical relief features of various parts of the State. Since many persons are not familiar with these maps and their uses, a brief explanation is here given.

These topographic maps, which are called sheets or quadrangles, are rectangular in shape and bounded by latitude and longitude lines. The size of each map is about 17½ inches high by 11½ to 16 inches wide, the latter varying with the latitude. In New York State the scale is nearly always 1 to 62,500 or nearly one mile to the inch, such a sheet or quadrangle covering an area of just one-sixteenth of a square degree. The most valuable feature of these maps is the fact that the surface configuration (relief) of the country is so accurately shown, this feature being explained by the accompanying figures and the following description which is generally found printed on the back of each map: "Relief is shown by contour lines in brown. Each contour passes through points which have the same altitude. One who follows a contour on the ground will go neither up hill nor down hill, but on a level. By the use of the contours not only are the shapes of the plains, hills, and mountains shown, but also the elevations. The line of the sea coast itself is a contour line, the datum or zero of elevation being the mean sea level. The contour line at, say, 20 feet above sea level is the line that would be the sea coast if the sea were to rise or the land to sink 20 feet. Such a line runs back into the valleys and forward around the points of hills and spurs. On a gentle slope this contour line is far from the present coast line, while on a steep slope it is near it. Thus a succession of these contour lines far apart on the map indicates a gentle slope; if close together, a steep slope; and if the contours run together in one line, as if each were vertically under the one above it, they indicate a cliff. . . . The contour interval, or vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval varies according to the character of the area mapped; in a flat country it may be as small as 5 feet; in a mountainous region it may be 200 feet. Certain contours, usually every fifth one, are accompanied by figures stating elevation above sea level. The heights of many definite points, such as road corners, railroad stations, railroad crossings, summits, water surfaces, triangulation stations, and bench marks, are also given. The figures in each case are placed close to the point to which they apply, and express the elevation to the nearest foot only. . . . All water features are shown in blue, the smaller streams and canals in full blue lines, and the larger streams, lakes, and the sea by blue water lining. . . . The works of man are shown in black, in which coloring all letter-

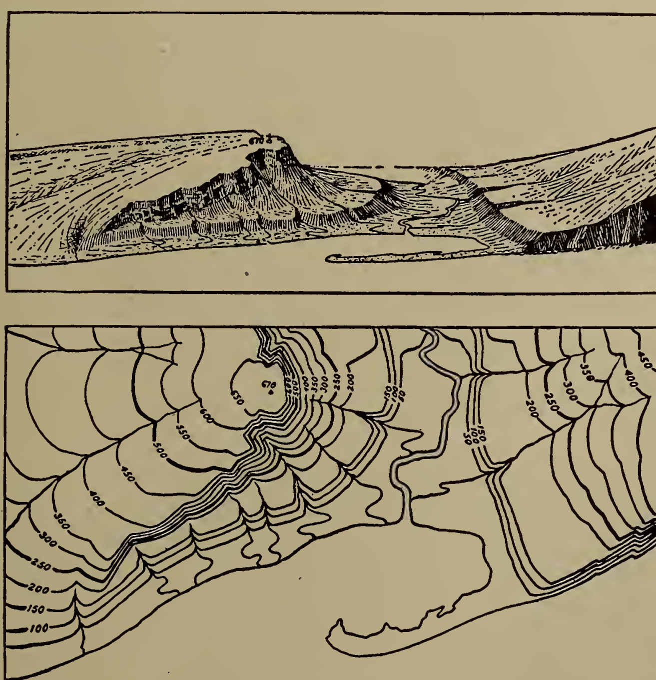


FIG. 40 Ideal sketch and corresponding contour map (U. S. G. S.).

ing also is printed. . . . Houses are shown by small black squares which in the densely built portions of cities and towns merge into blocks. Roads are shown by fine double lines, trails by single dotted lines, and railroads by full black lines with cross lines. Other cultural features are represented by conventions which are easily understood. The sheets composing the topographic atlas are designated by the name of a principal town or of some prominent natural feature within the quadrangle and the names of the adjoining published sheets are printed on the margins. They are sold at ten cents each when fewer than 50 copies are purchased, but when ordered in lots of 50 or more copies, whether of the same or of different sheets, the price is six cents each."

These maps are published by the United States Geological Survey, and orders for them should be sent to the director of that bureau at Washington, D. C. The order should be accompanied by cash or a post office money order. Each quadrangle has a special name by which it must be ordered. A large portion of New York State has been covered by such topographic surveys and, in order to know how to get the map covering a given region, reference should be made to the Index to Atlas Sheets for New York State. This index may be procured free of charge by dropping a post card to the Director of the United States Geological Survey.

The value of these maps to teachers of geography and physical geography would be difficult to overestimate, and every school should have a supply of these maps readily accessible. For the teaching of home geography as well as that of other parts of the State, for example, Niagara Falls, the Thousand Islands, New York City and vicinity, etc., no other map is comparable because, in addition to the ordinary features, the relief (topography) of the land is shown in detail. In other states, also, many places of importance or geographic interest have been covered by such maps.

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INDEX

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New York State Museum

John M. Clarke, Director

Museum Bulletin 169

GEOLOGY OF SARATOGA SPRINGS AND VICINITY

BY

H. P. CUSHING AND R. RUEDEMANN

New York State Education Department
Science Division, March 28, 1913

Hon. Andrew S. Draper LL.D.
Commissioner of Education

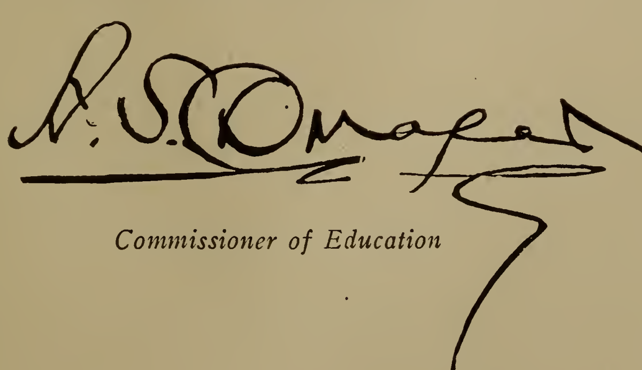
SIR: I have the honor to communicate herewith, and to recommend for publication as a bulletin of the State Museum, a manuscript entitled the *Geology of Saratoga Springs and Vicinity*, with the necessary illustrative matter accompanying.

This report has been prepared at my request by Doctors Cushing and Ruedemann, in response to a public demand for information in regard to the geological conditions existing about and causing the Saratoga mineral springs.

Very respectfully
JOHN M. CLARKE
Director

STATE OF NEW YORK
EDUCATION DEPARTMENT
COMMISSIONER'S ROOM

Approved for publication this 3d day of April 1913



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GEOLOGY OF SARATOGA SPRINGS AND VICINITY

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INTRODUCTION

BY H. P. CUSHING

The presence of a group of well-known springs whose waters are of a somewhat unusual type, has long given prominence to the region about Saratoga. A variety of causes has recently increased this prominence and rendered it desirable that the geology of the region should undergo more thorough investigation than it had ever received, in the hope that light might be shed upon the question of the origin of the waters and the duration of the supply.

It was the original plan to include in this report the geology of the Broadalbin quadrangle, next west of Saratoga, which was assigned to Dr W. J. Miller, but later developments led to the abandonment of this plan and Doctor Miller's report has been published separately.[1] That work was done in close association with our own, and in addition Doctor Miller also mapped some 30 square miles in the extreme northwest corner of the Saratoga quadrangle. This service is emphatically acknowledged since the country concerned is unsettled and difficult of access, and the aid was rendered at a time when the writer was unable to engage in field work as laborious as that which this district entailed. With this exception, Doctor Ruedemann and myself are responsible for the mapping. Much of the territory we have seen together.

[1] N. Y. State Mus. Bul. 153.

The classifying and mapping of the shales is wholly Doctor Ruedemann's; and the whole Schuylerville quadrangle also with the trifling exception of the extreme northwest corner.

During the progress of the work an invitation was extended to Prof. J. F. Kemp to collaborate in the study of the spring waters. Circumstances later developed which rendered it advisable to publish the report which he drew up as a separate paper and in advance of the main report.[1] The aid rendered is gratefully acknowledged.

During the progress of the field work several geologists have spent some time with us on the ground, and given most helpful suggestion and counsel. Days spent with Messrs Ulrich, Kemp, Smyth, Van Ingen and Miller are in no slight degree responsible for whatever of merit may lie in this report.

Over much of the Saratoga sheet glacial drift is so widespread and thick as to render hopeless the attempt to accurately map the geology beneath, which is peculiarly unfortunate because the geology is complicated and difficult. This has been the chief, and a very great, drawback to the successful prosecution of the work.

LOCATION AND CHARACTER

BY H. P. CUSHING

These two quadrangles, the Saratoga and Schuylerville, lie in extreme eastern New York, about midway of the State from north to south. The territory included lies between latitude 43° and 43° 15′ N, and longitude 73° 30′ and 74° W, hence extending over ¼° of latitude and ½° of longitude. It falls just short of containing 450 square miles.

The district includes parts of several topographic and geologic provinces. Bits of the southeast margin of the Adirondack highland, included by Powell in the province he called the New England plateaus, are seen. This highland is separated from the high Appalachian plateau of southern New York by the Mohawk valley lowland, a valley eaten out by stream erosion along the belt of weak shales which are the surface rocks through most of it. To this lowland belong the shales of the southern part of the Saratoga quadrangle.

The Adirondack highland is separated from the main mass of the New England plateaus by the low grounds of the Champlain-

[1] N. Y. State Mus. Bul. 159.

Hudson trough. This is not a mere valley of erosion but a true trough, having been repeatedly depressed as compared with the districts east and west of it. Erosion has had its part in the development of the valley, but as a secondary instead of a primary factor. In the mapped district this lowland is seen merging into the Mohawk lowland. Across the Hudson, along the east margin of the Schuylerville sheet, rises a range of hills, the outlying western rampart of the New England plateaus.

Turning from topography to geology we find the old crystalline rocks of the Adirondacks coming into the district from the north. These are margined by the flat-lying sandstones, limestones and shales of early Paleozoic age which were deposited in the Champlain basin, even in that early time a sinking trough. These in turn are adjoined on the east by the series of much disturbed shales of the Hudson valley, a quite different series of rocks from those of the Champlain basin. They were deposited, also in early Paleozoic times, in a wholly separate and more easterly trough than the Champlain basin, and have been brought to their present location by being thrust over to the west by the action of great compressive forces. As rocks they are not indigenous to the region, but exotic. Still farther east come the limestones and impure shaly rocks of the Bald Mountain ridge, also overthrust into the district from the east. These rocks are so different from those of the Champlain basin that we are of necessity constrained to describe and discuss them in separate chapters.

In two minor features the geology of the region is unique. One of the Paleozoic formations of the Champlain basin, the fossiliferous, Upper Cambric limestone which was first described by Walcott, occurs as a surface formation in New York only in the immediate vicinity of Saratoga.[1] Just north of Schuylerville there outcrops a knob of extrusive igneous rock, first recognized and described by Woodworth, which is unlike any other known igneous rock of the State, and which has been made to play a part in one theory of the origin of the spring waters.[2]

[1] U. S. Geol. Surv., Bul. 30, p. 21–22.

[2] N. Y. State Geol. 21st Ann. Rep't, p. r17–r29, 1901.

GENERAL TOPOGRAPHY

BY H. P. CUSHING

ADIRONDACK HIGHLAND

The surface rocks of the Adirondack highland are ancient crystalline rocks of Precambric age. The district is one with an inherent tendency to be elevated and to move upward rather than downward, or at least not to participate in the sagging tendency of adjacent territory during times of oscillations in the crust of the earth. Such a region is spoken of as a positive one, to distinguish it from districts of the negative type, whose tendency is to depress. At certain times in the past the margins of the highland have been sufficiently depressed to pass beneath sea level and become covered by marine deposits. But the central area of the plateau seems never to have been depressed in this manner, or at least not since very early in Precambric time; since then it has had a continuous existence as a land area. From time to time it has been uplifted and its surface has experienced much erosion. Between the periodic uplifts long ages of stability have intervened. During these stable intervals the surface has been the scene of incessant erosion, chiefly by stream and rain action. The ultimate effect of such prolonged erosion on a stable land area is to wear it down to a comparatively even surface with low altitude. Such an erosion plain is called a peneplain. If a peneplained district be again uplifted, stream activity is renewed and the whole erosion process again set in motion.

The Adirondack highland has certainly been peneplained twice during its history, and quite likely more than twice. The earlier of the two peneplains was completed in Precambric time, and it was upon this peneplained surface that the early Paleozoic deposits of northern New York were laid down, about the margins of the Adirondacks. These covered and preserved this old erosion surface and portions of it are reappearing at the present-day surface, as the Paleozoic cover is stripped away from it by modern erosion.[1] Its comparative evenness is surprising, when the great variation of the rocks composing it in resistance to erosion is considered.

In considerable part the present Precambric surfaces of the Saratoga quadrangle represent fragments of this old peneplain, though somewhat modified by comparatively modern erosion. This Precambric peneplain was developed over a wide area and is

[1] N. Y. State Mus. Bul. 145, p. 54–60.

recognizable over a large part of Canada and in the Upper Lake region as well as in the Adirondacks.

A much later peneplain, of probable late Mesozoic date, was also developed in the region, and again it was merely the local development of a peneplain of wide extent in eastern North America. Prior to its development, deformation of the region had upwarped the older peneplain into the form of a gentle dome, and at the same time downwarped the margins into shallow troughs in which early Paleozoic sandstones, limestones and shales had been deposited. The Mesozoic peneplain truncated the domed summit of the older peneplain; but on the margins of the region the two surfaces intersect and the older passes beneath the younger. The Paleozoic rocks lie upon the surface of the older, and the younger cuts across them (figure 1). An attempt to illustrate the manner in which, by erosional stripping back of the Paleozoic cover, portions of the old peneplain surface are exposed to view at the margins of the Adirondacks, is seen in figure 2.

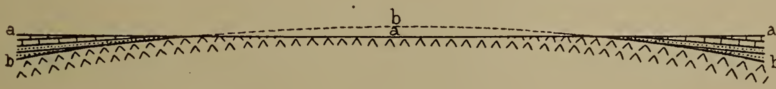

Fig. 1 Domed surface of Precambric peneplain, *b b b*, with marginal Paleozoic deposits, both truncated by late Mesozoic peneplain, *a a a*. Vertical scale much exaggerated.

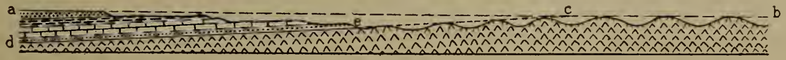

Fig. 2 Diagram in illustration of the manner of reaapearance of the old Precambric peneplain at the present surface; *a b* = late Mesozoic peneplain; *c d* = tipped surface of old peneplain, in part covered by Paleozoic rocks; from *c* to *c*, however, the Paleozoics have been recently removed by erosion, reexposing the old peneplain surface; modern erosion has cut valleys in both peneplain surfaces, but the ridge summits are remnants of these surfaces.

Since the development of the Mesozoic peneplain the highland has been again uplifted, the uplift being greatest along the eastern border. This has given the peneplain surfaces a tilt to the west. Since this uplift the present valleys of the region have been cut below the surface of the Mesozoic peneplain and, on belts of weak rocks, have become broadly developed. The entire surface of the Saratoga and Schuylerville quadrangles is below the level of the peneplain, with the possible exception of the hill summits in the vicinity of Black lake. The uplift was accompanied by dislocations of the peneplain surface, owing to movements along the great fault planes of the region, which broke up the uniform surface into a mosaic of flat-topped blocks at varying levels. Because of this dislocation and the modifying effects of subsequent erosion, the recognition of the peneplain surface in the eastern Adirondacks is a matter of considerable difficulty. The western Adirondacks were uplifted without dislocation, and there the peneplain is easily recognized.

The Adirondack highland is a moderately rugged region with much bare rock and comparatively little good soil, and is forest-covered throughout. In winter it is tenanted by the lumberman, in summer by the tourist and the river-driver. The population is scanty and scattered. The region is strangely poor in mineral wealth. But the forest and the water power are of great value; and no less so are the invigorating climate and the charm and beauty of wood and water.

THE MOHAWK LOWLAND

Since the uplift of the Mesozoic peneplain, the weaker rocks of the region have been deeply eroded. Along belts of weak rock, valleys have been carved, the valley bottoms representing the beginning of development of a new and lower peneplain. Not far south of the Adirondacks runs a great, east-west belt of weak shales, and into them the valley of the Mohawk has been carved as a great belt of lowland between the Adirondack plateau on the north and the plateau of southern New York. Great faults cross the valley bringing up masses of more resistant rock, as at Little Falls, St Johnsville, Sprakers, Tribes Hill and Hoffmans Ferry, and in these the lower valley narrows and its walls steepen. Otherwise the valley is broad and wide.

East of Hoffmans it becomes especially wide, on approach to the region of deformed rocks of eastern New York, in which the strike of the rocks approximates a north-south direction. The belt of shale broadens northward, curving around to merge with the Hudson valley lowland.

HUDSON VALLEY LOWLAND

From Fort Edward to Poughkeepsie the Hudson occupies a broad, often very broad, valley eroded in a belt of soft shales, quite similar to the Mohawk valley. The shales are also of quite similar character. But unlike the shale belt of the Mohawk, these shales are greatly deformed. They have been compressed, folded and faulted, and show steep dips nearly everywhere, instead of lying flat. The boundary between the two shale belts is fairly abrupt, and is readily traced across the Saratoga district. The shales of the Saratoga quadrangle are the undisturbed shales of the Mohawk belt, while the greater part of those of the Schuylerville quadrangle are the tipped shales of the Hudson valley belt. The greater part of the Schuylerville quadrangle is included in the Hudson lowland.

There are occasional harder bands in these tipped shales, bands of hard sandstone or grit and chert, whose lines of outcrop form low ridges on the otherwise level valley floor. Glacial deposits also diversify it somewhat, as they do along the Mohawk. Close to the river they have been washed away, but back from it they rise in prominent benches and widely cover the valley floor so that rock outcrops are very exceptional.

Two hilly tracts of land rise from this plain, one east of Saratoga lake, culminating between Ketchums Corners and Quaker Springs and attaining the 600 feet level; the other in the northeast corner of the Schuylerville sheet, north of the bend in the Moses kill. A landmark in the broad plain north of Fish creek is Kendrick's hill rising 200 feet above the plain.

The hilly region at the eastern edge of the Schuylerville sheet is the western margin of a plateau of somewhat higher level. This plateau is but little higher than the Hudson river plain; its base is about 400 feet above sea in the west and it rises gradually to about 600 feet across the adjoining Cambridge sheet to the eastern edge of that sheet, where another somewhat abrupt rise takes place to a higher plateau. We will call this lower plateau, which is about 10 miles wide, the Greenwich plateau. It can be traced on the east side of the Hudson across the Hoosic into Rensselaer county and south, where it lies in front of the Rensselaer plateau and has been fully described by Dale.[1] This plateau is characterized by its extremely irregular surface, as shown on the eastern edge of the Schuylerville sheet. It is covered with a great number of more or less oval hillocks, mostly but a few hundred feet high, but in many cases rising 500 feet, and in some even a thousand feet above the plain. It gradually approaches the Hudson river until at Troy

[1] Dale, T. Nelson. Geology of the Hudson Valley between the Hoosic and the Kinderhook. U. S. Geol. Surv. Bul. 242. 1904.

it forms the bluffs of the east bank of the river and thence merges into the Hudson river plain.

DRAINAGE

The two quadrangles drain entirely into the Hudson, the Schuylerville directly, the larger part of the Saratoga indirectly. The chief portion of the latter drains through Kayaderosseras creek into Saratoga lake, and thence by Fish creek into the Hudson, while the extreme northwest reaches the river by the still more indirect route of the Sacandaga.

Across the Schuylerville quadrangle flows the Hudson through the structural valley of the lowland just described. In structure this valley is the direct continuation southward of the Champlain-Wood creek valley. The Hudson enters this valley at Fort Edward, north of which there is a low divide of Pleistocene materials between the Hudson drainage and Wood creek. Between Corinth and Fort Edward the present position of the Hudson was never before occupied by a large stream, but is apparently a composite of portions of the narrow valleys of small preglacial streams. A small portion of this stretch of the river's course is seen on the two quadrangles, the remainder lying within the Glens Falls sheet. In this part of its course it shows frequent and abrupt changes in direction, abrupt variations in width, and frequent falls and rapids. At Corinth the water level is 520 feet, at Fort Edward 140 feet, and the distance is less than 12 miles in an air line, though much more following the river. This is a fall of over 30 feet to the mile.

At Corinth the river is in another structural valley of good size, which in preglacial times must have been occupied by a considerable stream. It has followed this valley for many miles through the mountains. Structurally this valley continues to the south across the Saratoga quadrangle and is now occupied by Kayaderosseras and Sturdevant creeks. It is heavily filled with Pleistocene deposits, especially at the north, and it was this depth of drift filling which turned the Hudson aside into its modern course through Glens Falls. The deeper channel of the valley is indicated on the areal map, and the valley continues on to the south past Ballston and through Ballston lake to the Mohawk at Schenectady.

In this vicinity, then, the present Hudson is occupying portions of two ancient, structural valleys, while its course from Corinth to

Fort Edward is its postglacial route of passage from the one to the other.

Aside from the river, the two principal streams of the district are Batten kill, coming into the river from the east, and the Kayaderosseras creek — Fish creek drainage from the west. This latter basin covers most of the Saratoga quadrangle and about one-third of the Schuylerville as well. Only the lower portion of Batten kill lies within the map limits, some 7 miles long following the stream, but only a little over 4 miles in an air line. In this short distance it drops over 200 feet. The larger part of this drop is made at Middle Falls and at the fall 1 mile below Middle Falls, unnamed on the map. This part of the stream's course is wholly modern and postglacial.

All the upper portion of Kayaderosseras creek lies in the deeply drift-filled, structural valley running south from Corinth. Heavy drift across the valley east of Middlegrove turns the stream aside and its course between Middlegrove and West Milton is modern and to the west of the old valley, with the chief drop at Rock City Falls. At West Milton it reenters and crosses the old valley, then turns south through Ballston in a modern course, with frequent rapids and falls. Below Ballston it flows through a shallow valley wholly in drift to Saratoga lake. Below the lake it is a sluggish stream with little fall in preexisting valleys until the big bend just below Victory Mills is reached. The final mile and a half of the stream is again in a modern channel, with a drop of nearly 100 feet.

On these three streams, because of their steep gradient, there are numerous water-power sites, all of which are occupied and in vigorous use. Few districts show as thorough utilization of power possibilities.

GLACIAL DEPOSITS

On the higher grounds of the district there is no great thickness of glacial deposit, and the topography and bedrock geology are well shown. But at the lower levels, and chiefly in the two great valleys, there is abundant and often thick drift, constituting an important element in the topography. This drift is in part glacially deposited and in part a water deposit.

MORAINES

No terminal moraine of any particular prominence lies within the map limits, though there is a considerable morainic belt running across the northern portion of the Saratoga quadrangle. But there is a tremendous lateral moraine terrace banked up against the mountain front along the west side of the Kayaderosseras valley and a smaller but similar one along the Mt McGregor front. These would seem to have been deposited along the sides of the ice lobes which occupied these valleys during the retreat of the last ice from the region. They are overspread with sand in varying amount, deposited from streams supplied by the melting ice, which flowed along the margins of the ice lobes between the ice and the valley wall.

DRUMLINS

These are oval-shaped hills of drift, chiefly till, supposedly formed underneath a glacier near its end. There is a group of ten or a dozen such hills in the Kayaderosseras valley, grouped in a rude triangle whose apex is the large drumlin just south of Kings, on the Adirondack branch of the Delaware & Hudson Railroad, and whose base extends across southern Greenfield township into northwest Milton. Shaped by the ice, the longer axes of such hills are supposed to trend with the direction of ice movement. In this group the trend varies from north-south to south 20° west. They show prominently on the topographic map.

A group of hills of similar appearance, east of Saratoga lake, Schuylerville quadrangle, are rock hills and not drumlins at all. Harder bands in the tipped shales, either chert or sandstone, are responsible for these hills.

TERRACES

There are several broad terraces of sand and gravel within the mapped limits, chiefly the delta deposits of streams formed during the ice retreat from the region. Batten kill built a great delta in the higher water levels of the time, forming a great terrace east of the Hudson, banked up against the base of the hills, from Bald mountain southward, the larger part of it being south of the present position of the stream.

Running southwest from Gansevoort through Wilton is a tremendous sand terrace, which continues on into confluence with the similar terrace to the east and south of Saratoga Springs. The summit levels of this terrace are quite like those of the Batten kill delta. Southwest of Saratoga Springs, in Milton township, is another great sand terrace, at a somewhat higher level than the other two. In the valley south of Corinth, hemmed in between the higher grounds on each side, is a smaller sand delta, at a much higher level.

The deposits of these terraces were laid down in close proximity to the ice sheet, occasionally covering stranded blocks of ice. When this melted away, depressions were left which became occupied by ponds. Three such ponds lie in the sands south of Corinth; and Moreau pond, northwest of Gansevoort, and Lonely lake near Saratoga lake, are larger examples. Saratoga lake itself lies in an old drainage valley, and in a portion of it which was less deeply filled with drift than the remainder.

GENERAL GEOLOGY

BY H. P. CUSHING

The surface rocks of the Saratoga and Schuylerville quadrangles belong apparently to two separate geologic provinces. The rocks of the Saratoga and the western portion of the Schuylerville quadrangle are those of the Adirondack plateau and the lower Mohawk trough; those of the remainder of the Schuylerville quadrangle are deposits of more eastern troughs. The Adirondack plateau rocks are of Precambric age and comprise both sedimentary and igneous rocks. Those of the Mohawk trough are of early Paleozoic age, Cambric and Ordovicic, and contain no igneous rocks in the Saratoga region. Those of the more easterly troughs are also of early Paleozoic age, Cambric and Ordovicic. But the formational units are quite different from those of the Mohawk trough, and the two are also very unlike structurally.

Except for the cover of comparatively recent deposits of Pleistocene age there are no rocks in the region younger than the Ordovicic, with one trifling exception, and that an igneous rock. A mile north of Schuylerville, on the west bank of the Hudson, is a small knob of extrusive rock of peculiar character, which is certainly younger than the Ordovicic and in all probability very much younger.

STRUCTURE

Since their formation the rocks of the Adirondack region and the Mohawk trough have been considerably deformed. The Precambric rocks of the Adirondacks were enormously deformed in Precambric time and folded in a complex manner, while the sediments were all cut to pieces by great intrusions of igneous rock from beneath.

Besides this early deformation the rocks of the eastern Adirondacks have undergone subsequent deformation, in common with the Paleozoic rocks of the Champlain valley. This has chiefly expressed itself in the formation of a great number of normal faults, both large and small. The Paleozoic rocks of the trough are but little folded and usually but slightly tilted, but they are cut into great slices by a series of normal faults which trend about north-northeast, and which are themselves broken by occasional cross faults. Most of these faults downthrow to the east, but at the same time the upthrow side is given a tilt to the west, forming a valley when combined with the upthrow side of the next fault to the west. Occasional faults throw to the west, with the result that a depressed structural valley called a graben is formed.

The drop from the level of the Adirondack highland to the low grounds of the Mohawk trough is produced by a series of these great faults, all throwing to the east.

Passing from the Mohawk rocks to those of the more easterly troughs, one finds a quite different kind of structures. In the first place the rocks are much more folded. The chief structures here are also faults, but instead of being nearly vertical and normal, they are quite flat and are overthrusts, along which great masses of rock have been pushed westward for miles. Unlike the Mohawk rocks, they now lie far from the area where they were originally deposited and form a jumble of overthrust masses. Their structure is exceedingly, often hopelessly, complicated.

DESCRIPTIVE GEOLOGY

BY H. P. CUSHING

The exposed rocks of the two quadrangles are of Precambric, Cambric and Ordovicic age, together with the unconsolidated deposits of Quaternary age and the small exposure of extrusive rock of unknown age north of Schuylerville.

PRECAMBRIC ROCKS

The Precambric rocks of the Adirondack region, so far as known, are comprised in an old series of sedimentary rocks, named the Grenville series, which are the oldest known rocks of the district, and in various masses of igneous rocks all of which cut the Grenville rocks intrusively and are therefore younger. The oldest of these igneous rocks is a granite called the Laurentian. Later than this came a series of intrusions, anorthosite, syenite, granite and gabbro, in the order named. These probably represent a group of closely related intrusions not widely separated in time from one another. Much later came renewed igneous activity with intrusion of diabase (trap), found exclusively as dikes cutting all the other Precambric rocks.

Representatives of all these rock groups occur in the Saratoga region. The Grenville rocks are abundantly represented; Laurentian granite is probably present, that is to say there is abundance of a granitic rock which we regard as probably Laurentian; the second group of intrusions is represented by abundant syenite and apparently by that alone; and occasional trap dikes of large size belong to the last group.

GRENVILLE SERIES

The Grenville series in the Adirondacks exhibits an enormous thickness of limestones, quartzites and various sorts of schists. On the Saratoga quadrangle the bulk of the Grenville consists of schists, but there is also a considerable amount of quartzite. Limestone is present only as occasional thin bands in the quartzite series. A few miles farther north, however, much more limestone comes in. A considerable belt in which there is much quartzite, interbedded with thin bands of schist and limestone, contrasts so strongly with the remainder of the Grenville that we have mapped it separately. With this exception the intricate admixture of various schists absolutely defies detailed mapping.

In addition, the series is everywhere cut to pieces by a white, granitic rock of somewhat peculiar type, that we have heretofore been regarding as a Grenville sediment. The reasons for regarding it as an igneous rock will shortly appear. We have mapped separately three areas of this rock, but the mapping is vague and highly conventional. The rock is found everywhere throughout the Grenville area, inextricably mingled with the schists. In these three areas it exceeds the schists in quantity and is mapped separately to give conventional expression to our views respecting its nature and relationships. We are provisionally regarding it as Laurentian, that being the term applied to the ancient granitic rocks which, throughout Canada, the Upper Lake region and the Adirondacks, invade and cut to pieces the oldest known clastic deposits. The uncertain feature of this correlation, so far as the Adirondacks is concerned, is that the Laurentian granite, in the Lake Superior region, is older than the Lower Huronian. hence the use of the term in the east necessitates holding either that the Grenville series is also older than the Lower Huronian, or that the Laurentian granite is younger than about Lake Superior, since the granite is certainly younger than the Grenville.

GRENVILLE SCHISTS

As has been stated, Grenville schists exist in such great variety and with such rapid alternations as to defy detailed mapping and to render detailed description laborious and profitless. The schists are everywhere intricately involved with hard, white, garnetiferous gneisses which, heretofore regarded as sediments, seem to the writer to be plainly igneous rocks. They cut the schists intrusively and develop pegmatites. In the majority of exposures they are merely injected along the foliation planes of the schist, forming injection gneisses and looking extremely like interbanded sediments. The more common of the schists are mica schists, and the prevailing Grenville combination of the quadrangle consists of the interbanded mica schist and white granite.

These mica schists vary from very weak rocks with abundant mica to much firmer ones in which mica is scant. Because of weakness, the former variety is seldom seen in outcrop, but several cuts through such schists expose them well along the Adirondack Railroad a mile north of Saratoga. The firmer varieties outcrop everywhere.

These schists are feldspar-quartz-mica combinations, and nearly everywhere contain in addition pink garnets. The mica is biotite and the bulk of the feldspar is plagioclase, oligoclase to andesine. Quartz forms in general from 10 to 25 per cent of the rock. Foliation is thorough and even.

On the one hand these mica schists grade over into amphibolites, which are heavy black gneisses composed essentially of plagioclase feldspar and hornblende, with usually black mica and pyroxene in addition; on the other hand they grade into hard, light colored feldspar-quartz gneisses, by diminution in the mica present.

The garnets seem to owe their origin to contact action of the white granite upon the schists, as will be later shown. Graphite is a frequent mineral in the schists.

The schists are in chief part metamorphosed shales, as indicated clearly by their composition and structure. They have been entirely recrystallized, injected in complex fashion by granite, and vastly changed in appearance and character. Originally they varied somewhat, clay shales alternating with sandy shales, and these with calcareous shales. These original variations are still discernible in the schists as bands of varying character, whose chief differences from one another are in the relative proportions of the three common minerals, quartz, feldspar and mica, which compose them.

Grenville amphibolite. There is not a great quantity of amphibolite in the Grenville of the Saratoga quadrangle, and such as there is occurs mingled with the other Grenville rocks in masses of no great size. It occurs in two different ways. On the one hand it forms comparatively thin bands, so interbedded with the other Grenville rocks as to make it highly probable that it represents a band of sediment, a probable original calcareous shale. These bands often appear to grade into the general schists which are interbedded with them. On the other hand it occurs in more or less oval masses which, notwithstanding their small size, seem to cut through the other Grenville rocks, instead of being interbedded, and hence to represent igneous rocks of somewhat later age instead of contemporary sediments. The former are commonly, though not always, heavier, denser and blacker rocks than the latter. Amphibolites of both types occur abundantly in the Adirondacks, but it is by no means always possible definitely to determine to which type a given occurrence belongs, especially when the masses are as small as on this quadrangle.

Grenville quartzite. The chief belt of Grenville rocks other than schists is an east-west belt about a mile in breadth of surface outcrop, which crosses the Saratoga quadrangle through Greenfield township from just west of Kings Station to Mt Pleasant. This is not a belt of solid quartzite, but consists of numerous beds of quartzite, interbanded with various schists and with thin beds of crystalline limestone. The central part of the belt, downfaulted into the Kayaderosseras valley, is covered by younger rocks. West of Mt Pleasant it is cut out by syenite. Though occurring in thin bands elsewhere, the Grenville quartzite and limestone of the quadrangle are practically confined to this belt.

The quartzites present substantially the same varieties as are common elsewhere in the Adirondacks. There are beds of coarsely crystalline, glassy looking quartz rocks, in which quartz constitutes from 70 to 90 per cent of the rock, and the remainder is chiefly feldspar. The finer grained quartzites are usually less quartzose, though with quartz always forming 50 per cent or more of the rock. They are usually quartz-feldspar or quartz-pyroxene rocks. The latter are less abundant about Saratoga than the former. They are often somewhat micaceous, a brown phlogopite being the usual mica. Pyrite is also a common mineral, and the pyritiferous quartzites, on weathered surface, have the pyrite weathered out and replaced by a brown limonite stain.

Much of the quartzite contains graphite sparingly. There is a thickness of at least 100 feet that contains it in sufficient quantity so that it has been worked for graphite at two different localities on the quadrangle, 1 mile southwest of Kings Station and 2 miles west of Porter Corners. The rock is quite similar at the two places, being granular and considerably altered. It is interbedded with quartzites and quartzose mica schists and is itself a graphitic quartz schist. At the Porter Corners locality the rock is a quartz-feldspar combination, about 50 per cent quartz, 40 per cent feldspar, and the remainder graphite and mica. In the special bed worked there is but little mica and nearly 10 per cent of graphite. Above and below more mica comes in. The feldspar is very badly altered.

At the Kings Station locality the rock is so similar as strongly to suggest the identity of the horizon. On first appearance, the rock seems richer in graphite than at Porter Corners, and may be so; but it certainly contains more mica than that, a disadvantage from the standpoint of successful working. The rock in both places is very similar to that which has been worked for years about Hague; and though it is quite possible that there may be more than one horizon of such graphitic quartzite in the Grenville, it seems more reasonable to assume but one, in default of definite evidence to the contrary.

Grenville limestone. But two beds of limestone were seen in the Grenville of the quadrangle, one noted only at the dam of the Kings Station graphite mill, the other in two localities, about a mile apart along the strike, between 3 and 4 miles west of north of Kings Station. Each is about 10 feet thick, impure, and closely associated with heavy, black amphibolites, which are very common border rocks to the limestones in the Adirondacks and were originally very impure limestones.

The limestone of these two beds is far from pure, the calcite constituting not over 50 per cent of the rock. The most common of the other constituents is quartz, but scapolite, pyroxene, phlogopite, graphite and titanite are also present. Much of the rock is fine grained and of a gray tint, instead of being the usual, coarsely crystalline, white marble of the region.

PRECAMBRIC IGNEOUS ROCKS

General statement. In order of age the Precambric igneous rocks of the quadrangles are the Laurentian (?) granite, the syenite, and the trap (diabase) dikes. There are in addition very small and occasional masses of amphibolite which are probably original gabbros and younger than the syenite, but they merit only passing notice because of their small bulk and problematic character.

Laurentian (?) granite. A previous statement makes reference to a white, granitic rock, intricately involved with the Grenville schists, which is a common constituent of the Grenville throughout the southern Adirondacks and which we have heretofore regarded as a Grenville rock. Thus Cushing, reporting upon similar rocks from the Little Falls quadrangle, classes them as Grenville.[1] Kemp and Hill describe the similar rock from the "Noses" in the Mohawk valley as a Grenville sediment.[2] The problem is an involved one since the granite is seldom pure but has everywhere taken in a considerable amount of the adjacent Grenville rocks, giving rise to a mixed rock composed of varying amounts of granite and schist. The recognition of pegmatitic phases of the rock threw the first doubt upon its sedimentary character; afterwards it came to be recognized that the granite itself, as well as its pegmatites, was intrusive as regards the schists. The chemical analysis eventually settled the question.

The granite is a difficult rock to describe because it is nearly everywhere so involved with the schists, or with material from the schists, as to make rock free from such contamination difficult of recognition. The mica is the most obvious of the contributions from the schist, which is certainly much richer in that mineral than the original granite. Hence arises a tendency to infer that those portions of the granite freest from mica are those least contaminated. Such portions show a very white rock composed of white feldspar and quartz and a very little black mica (biotite). In addition are small amounts of apatite, titanite, zircon, and magnetite. Pink garnets are always present but are not regarded as original minerals of the rock. They are most abundant in the schists which have been thoroughly impregnated with granite, and have in most cases resulted from corrosive interaction between the minerals of the two rocks. In other words, most of the garnet is

[1] N. Y. State Mus. Bul. 77, p. 17–19.

[2] N. Y. State Geol. 19th Ann. Rep't p. r32–r35.

a contact mineral. Its occurrence in the pegmatites, however, suggests caution in ascribing it all to such a source.

The granite is chiefly found thoroughly interbanded with the schists, injected into them parallel with their foliation, forming apparent beds of hard, white gneiss which alternate with those of schist. The beds vary in thickness from a few feet to many. It is only in exceptional cases that the granite can be seen to cut across the schist foliation. It is quite otherwise with the pegmatite dikes from the granite which cut it and the schists in all directions, and seldom follow the foliation. In the three small areas which we have mapped as granite, the rock is full of schist, ranging from mere films to bands many feet thick. These are all thought to be stretched inclusions, though it is seldom possible to demonstrate this. The bordering areas mapped as schist are likewise full of granite and pegmatite dikes, so that the mapping is highly conventional and merely roughly distinguishes areas in which granite is in excess from those in which the schist predominates. But the relations are much less simple and obvious than in the Thousand Islands region where what we regard as similar relations between Grenville and granite obtain. In passing across the Adirondacks from west to east the Precambric rocks show a steady increase in complexity because of ever more severe metamorphism, until eventually, in the extreme east, the whole series has been so enormously compressed and stretched that it is no longer easy to recognize inclusions of sediments in igneous rocks, or dikes of igneous rocks in sediments, owing to the apparent interbanding.

There has also been much intermediate rock produced by a thorough interpenetration of the schist by the granite. The exposed granite masses are small, and we have not noted the evidence of the actual digestion of schist by granite, with production of rock of intermediate character, such as may be seen in the cases of the larger batholiths of Laurentian granite. There has been much injection of schist by granite, however, both along the foliation planes with production of injection gneiss, and also of the mosaic type in which the granite minutely penetrates the schist everywhere. In many bands of this type an enormous amount of garnet has developed.

The pegmatites. It was the abundant dikes of white granite pegmatite that first suggested the igneous nature of the white gneiss and furnishes the chief evidence for it, aside from the chemical composition. They cut through the granite everywhere and also through the surrounding schists. Except for being usually more quartzose they are quite like the granite in mineralogy, coarsely crystalline aggregates of quartz and white feldspars (microperthite and oligoclase) with some biotite and often garnets. The schists just to the north of Saratoga, as shown along the Adirondack Railroad and along the north margin of Highland park, are full of these dikes; and a little farther north, along the fault scarp, the granite shows well and accessibly and has been quarried somewhat. In addition to the usual minerals these dikes show here and there other and rarer minerals. The old chrysoberyl locality, just to the north of Saratoga, is on one of these dikes in the schist. In this a lot of black tourmaline has developed, so that the pegmatite is a quartz-feldspar-tourmaline-garnet rock, in which frequent nests of chrysoberyl crystals occur. The dike cuts a hard mica gneiss and is about 3 feet wide at the old pit. One and one-half miles south of South Corinth is another old mineral pit on a pegmatite vein in schists, which furnished fine black tourmaline and rose quartz.

Mixed rock. With the exception of the pegmatites practically all the granite is contaminated with schist. We interpret this contamination as resulting from the shredding and dispersion of the schist inclusions in the granite under conditions of extreme pressure and metamorphism. All gradations occur between bands of schist somewhat impregnated by granite and granite that seems normal except for the fact that it may be somewhat more micaceous than it should be. This introduces an element of uncertainty in the attempt to investigate the granite chemically.

Chemical composition. The material chosen for analysis was obtained from the quarry in the granite on the face of the fault scarp 2 miles north of Saratoga, and was chosen because it was fresh and because contamination with schist seemed slight, if any. The thin section showed quartz, about 25 per cent, feldspars about equally divided between oligoclase on the one hand and microcline and microperthite on the other, about 70 per cent, and the remainder biotite, except for a few small zircons and a trifle of apatite and titanite. The hand specimen shows occasional garnets, none of which got into the thin section. The rock shows a rude banding due to variations in the amount of mica, suggesting a trifle of shredded schist in the more micaceous bands, but not enough to impair materially the value of Doctor Morley's analysis.

	1	2	3	4	5
SiO_2	72.41	73.33	73.10	70.13	1.207
Al_2O_3	13.85	13.55	14.29	15.47	.136
Fe_2O_3	1.13	.58	1.04	1.52	.007
FeO	1.57	1.53	1.04	1.05	.022
MgO	.45	.45	.53	.85	.011
CaO	1.54	1.66	1.18	1.60	.028
Na_2O	4.31	5.01	3.08	3.72	.069
K_2O	3.68	3.12	5.36	4.39	.040
H_2O+	.41	.45	.54	.48	....
H_2O-	....	....	.07	.01	....
TiO_2	.44	.17	.18	.30	.005
P_2O_5	.07	....	.03	....	.0005
Cl	....	....	.03	.05	....
F	.01	....	.02	.09	.0005
S	.05	....	.02	.07	....
MnO	.33	.04	.07	.08	.004
BaO	.03	....	....	.05	....
	100.28	99.89	100.58	99.86	

1 White granite (Laurentian?) from 2 miles north of Saratoga. E. W. Morley, analyst.

2 Laurentian granite gneiss from the Methuen bathylith of central Ontario. F. D. Adams, Jour. Geol., 17:17.

3 Laurentian granite gneiss of the Alexandria bathylith. E. W. Morley, analyst, N. Y. State Mus. Bul. 145, p. 176.

4 Laurentian granite gneiss of the Antwerp bathylith of northwestern New York, granite with slight amphibolite contamination. E. W. Morley, analyst, N. Y. State Mus. Bul. 145, p. 176.

5 Molecular ratios of analysis no. 1.

A comparison of the four analyses given brings out at a glance the practical identity of the Saratoga rock with those of Ontario and northwestern New York. They differ only in the alkali ratio, soda exceeding potash in the rock from Ontario, and the reverse being true in that from northwestern New York. In this respect the Saratoga rock is more like that from Ontario, though occupying an intermediate position. That this would be the case was indicated in the thin section, oligoclase being much more abundant and microperthite correspondingly less so than in the rocks from the Thousand Islands region. We regard the chemical evidence as strongly corroborative of the impression gained in the field regarding the igneous nature of this white gneiss.

The norm of the rock of analysis 1 is as follows:

Orthoclase	22.24	94.34	Class 1, persalane
Albite	36.15		
Anorthite	6.95		Order 4, britannare
Quartz	28.80		
Corundum	0.20		Rang 2, toscanase
Hypersthene	2.60	5.15	Subrang 4, lassenose
Magnetite	1.62		
Ilmenite	0.76		$K_2O : Na_2O :: 3 : 5.2$
Apatite	0.17		

The northwestern New York granites belong in subrang 3, toscanose, while the Ontarian rock is a distinct lassenose. The Saratoga rock is on the border between the two subrangs as the alkali ratio shows.

The rock differs considerably in appearance from the usual Laurentian granite of Canada and northern New York, the chief differences being the white color and the content of pink garnet. In the Thousand Islands region we have shown that the red Laurentian granites have their red feldspars bleached to white in the vicinity of Grenville limestones.[1] We have seen similar bleached granites in Ontario in like situation. About Saratoga the granite masses are small and suggest that erosion here is just beginning to uncover a granite bathylith and has reached only a few of the higher protuberances, full of included rock masses. This might suggest that the granite would run into red rock in depth, but the matter is not urged since the chief inclosing rocks are schists which are poor in lime.

Because it gives rise to pegmatites and has the composition of a granite, this rock is regarded as igneous. It is further regarded as Laurentian for two reasons: first, because it is distinctly older than the syenite which cuts it intrusively just as it cuts the Grenville; and second, because it also shows its great age by the intricate manner in which it is involved with the Grenville and has been metamorphosed in common with it. In the latter respect it furnishes a strong contrast with the Laurentian granites of northwestern New York, whose relations with the Grenville are much less involved and more obvious. This contrast is to be attributed to the fact that the Precambric rocks of the Adirondacks show a

[1] N. Y. State Mus. Bul. 145, p. 46–7, 177–180.

progressive increase in amount of metamorphism from west to east, so that, when the eastern border is reached, the relations of the rock groups to one another have become much disguised and difficult to decipher. If this white rock be really an igneous granite, then its relations to the Grenville are apparently just those which are diagnostic of the Laurentian in western New York and in Ontario. The apparently confused commingling of the two rocks, the apparent interbedding, and the abundant development of pink garnet both in the schists and in the intrusive, are the expression of the greater severity of metamorphism.

The syenite. The surface rocks of much of the Adirondack region are intrusive igneous rocks of early Precambric age, but younger than the Grenville and the Laurentian. There are four groups of these rocks — anorthosite, syenite, gabbro and granite — named in order of age. The first two occur in much greater volume than the last two. In distribution, the anorthosite differs from the syenite in occuring chiefly in a single great bathylitic mass whose area at the present-day surface is about 1500 square miles in the eastern and central Adirondacks. There are small outlying masses to be sure, but neither abundant enough nor large enough materially to qualify the general statement. The southern edge of this mass is well north of the Saratoga quadrangle so that, except for an occasional glacial boulder, the rock is not found here.

The syenite contrasts quite sharply with the anorthosite in distribution. Instead of appearing in one huge mass it forms many small ones; instead of being an abundant rock in part of the region and wholly lacking in the remainder, it is found everywhere throughout the Adirondacks. Every detailed map of part of the region shows it present; and we know also that it is abundantly present in the remainder which has been covered merely by reconnaissance work. Because of this scattered distribution we are wholly unable as yet to give any estimate of any value concerning the area which the rock occupies; we can, however, now say that syenite is the surface rock of a much greater area in the Adirondacks than that occupied by anorthosite, large as the latter is, and that the area of syenite is a notable one when compared with any other known area the world over.

There are three main areas of syenite within the mapped limits. The largest is the one which forms the main mass of the Mt McGregor range and its back country. The modern gorge of the

Hudson cuts through this mass, some quarrying has been done in it to furnish masonry for Spiers dam, and hence the general exhibit of the rock along the river is the best to be found within the quadrangles. Up the hill west of Corinth is the southern half to two-thirds of another mass running north on to the Luzerne sheet; and the third area runs west from Lake Desolation and Mt Pleasant and its western extension may be seen on the map of the Broadalbin quadrangle.[1] It should be clearly understood that the boundaries between the syenite and the Grenville, as drawn on the maps, are of the most vague description. A multitude of dikes run out from the syenite into the Grenville; the syenite is full of inclusions of Grenville and the whole combination has been much deformed. There is plenty of syenite outside the areas mapped as such and there is much Grenville within the areas mapped as syenite. The best that can be done on maps of this scale is to endeavor to map as syenite, areas in which this rock constitutes more than 50 per cent of the whole, and as Grenville those in which the syenite constitutes less than 50 per cent.

The syenites have been described in detail, with chemical analyses in so many of the New York State Museum bulletins that it seems superfluous to repeat the discussion here.[2] As shown on the quadrangle, they are usually greenish gray rocks, sometimes blotched with red and grading into varieties richer in quartz and wholly red. The rock is thoroughly gneissoid. The most interesting thing about it is the way in which it uniformly runs over into coarsely porphyritic varieties at the margins and in the dikes of syenite in the Grenville. The porphyritic crystals, usually called augen, are often large, reaching a length of 2 inches, while those of an inch in length are very common; the feldspar of these augen is usually red, the augen are aligned parallel to the foliation, and in many cases are partly or wholly crushed or granulated. In the body of the rock, mica has developed in quantity and the resemblance to a metamorphosed conglomerate is strong. The rock is considerably more quartzose and acid than the main body of the syenite.

In the description of the Alexandria syenite of the Alexandria quadrangle, a similar porphyritic, marginal phase of the rock was described, but some doubt was expressed as to whether it was in

[1] W. J. Miller, map accompanying N. Y. State Mus. Bul. 153.

[2] Bul. 95, p. 312–40; Bul. 115, p.512–25; Bul. 138, p. 44–52; Bul. 145, p. 182–84; Bul. 153, p. 14–21.

reality a marginal part of the same intrusion, or a separate intrusion.[1] The porphyritic border phases of the rock as they occur about Saratoga, where the relation to the main rock is certain, are so precisely like this porphyritic rock from Alexandria as to leave no doubt in our mind that this is also a border phase of the syenite intrusion. Such border phases of the rock, of porphyritic nature, are proving a quite normal feature of the syenite of the region.

The rock here varies about as it does elsewhere except that the more basic phases are lacking. Granitic varieties, however, are abundant. This seems to us likely due to the fact that the surrounding rocks in the quadrangle are mostly of siliceous nature. Much more than in the case of the other intrusives of the region there is found for the syenite a usual relation between the nature of its border phase and the character of the neighboring rock; such a relation as indicated by Kemp for the occurrences of the Elizabethtown quadrangle, and by the writer for the Long Lake quadrangle.[2]

But one variety of syenite on the quadrangle seems sufficiently novel to merit special notice. In the quarry by the Hudson near Spiers dam, is a very gneissoid dark green variety of syenite, one of the many varieties occurring there, which is really not a syenite at all, but diorite, 80 per cent of its feldspar being andesine (about Ab_3An_2). Pyroxene, hornblende, biotite, magnetite, apatite and zircon form about 15 per cent of the rock, some 7 per cent is quartz, and the remainder feldspar. The excellent exhibit of the rock shown in the quarry shows rapid and great range in composition, bands of granite, syenite and diorite appearing. All are plainly varieties of the one rock type. The material is almost precisely like the syenite at Little Falls in appearance and in variation, except that at Little Falls the variation between extreme types is not usually so rapid. In these very gneissoid syenites of the east, garnet is a more common mineral than in the mid-Adirondacks or on the west. There it is usually confined to the basic, border phases, or to the narrow dikes, whereas here it comes quite frequently as a constituent of the normal and the acid varieties.

Diabase dikes of late Precambric age. Nearly everywhere in the Adirondacks all the other Precambric rocks are found cut by

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[1] N. Y. State Mus. Bul. 145, p. 39–40, 182–84.

[2] N. Y. State Mus. Bul. 138, p. 81; N. Y. State Mus. Mul. 115, p. 478–79.

dikes of unmetamorphosed, igneous rock. Their greater youth is shown by the fact that they cut all the other rocks. As all the other rocks have been more or less metamorphosed, and these have not, they are likely considerably younger. They are found in all parts of the region but most abundantly in Clinton county, on the extreme northeast, whence they diminish in number to the south and west. In the central and western Adirondacks they are comparatively scarce. On the extreme northwest, in the Thousand Islands region, they become again abundant. They are older than the Potsdam sandstone, the oldest Paleozoic rock of the region, and hence are of age intermediate between it and the other Precambric rocks, and likely of late Precambric age.

There are two chief varieties of these rocks: heavy, black traps, and less dense syenite rocks of red color. The latter have been so far found only in Clinton county, but the trap dikes range throughout the region. They are not particularly abundant in the Saratoga region, but those that do occur make up for their infrequency by their size. The usual trap dikes of the region range from 1 foot to 30 feet in thickness. Most of those near Saratoga are from 50 to 100 feet thick, and we have traced some of them for several miles. Thus the dike numbered 1 upon the Saratoga quadrangle, the one quarried for road metal north of the village, can be followed foot by foot for 2 miles north and south of the quarry, with an average width of from 75 to 100 feet. To the north it runs into low, swampy ground for 2 miles but beyond that and precisely on the trend of this dike we have repeatedly found a huge dike of the same width, for an additional distance of 7 miles more, which we confidently assume to be the same dike. Both to the east and west of this big dike are others which have been traced for several miles, and are 50 feet or more in width.

These are all ordinary diabases. Olivine has not been identified with certainty in any of them. They are labradorite, augite, magnetite rocks with good ophitic structure. All are considerably altered. It is exceptional to find the augite in fresh condition, and much of the feldspar is also altered. In this respect the dikes show sharp contrast with those of the northern Adirondacks where the larger number of the dikes are very fresh. This we attribute to the more vigorous glacial erosion on the north.

A table of analyses of Adirondack diabases has been recently published by Kemp, to which reference may be made by such as are interested in this subject.[1]

STRUCTURES OF THE PRECAMBRIC ROCKS

Foliation. The foliation or cleavage, the most conspicuous structure of the Precambric rocks, is found in sediments and igneous rocks alike, the trap dikes excepted. But the sediments are better foliated than the igneous rocks. The foliation of the Grenville rocks of the Saratoga region is parallel to the bedding, so that the directions of the two are equivalent. This seems to be the general relation of the two in the Adirondacks, as suggested years ago by Van Hise.[2]

The foliation strike over much of the Saratoga quadrangle is nearly east-west, and the dips are to the south and rather flat, seldom reaching 45°. The strike swerves to the northwest in the northeast portion of the quadrangle, and to the northeast in the northwest portion, though the dips remain to the south. This is not in accord with the usual direction in the Adirondacks where the prevailing strikes are northeast. As elsewhere a great monocline of the rocks is suggested; and, as elsewhere, this makes a Grenville succession of enormous thickness, so thick as to suggest caution in interpretation of the structure and as to emphasize the probability of the alternative suggestion that the rocks are closely pinched and folded, in a series of closed, overturned folds.

Faults. The great faults of the district are of much later date than the Precambric, and dislocate Precambric and Paleozoic rocks alike. But here, as elsewhere in the region, small faults are noted in the Precambric rocks of such character that they seem surely of Precambric age. We have found as yet no certain evidence of large faults of this early date.

PALEOZOIC ROCKS OF THE WESTERN TROUGH

BY H. P. CUSHING

The terms eastern and western troughs as used in this report have no significance other than convenience in description, and imply merely the relative positions of two contrasted sets of

[1] N. Y. State Mus. Bul. 138, p. 60–61.
[2] U. S. Geol. Surv. 16th Ann. Rep't, pt 1, p. 773.

Paleozoic formations. The western trough, which has been called the Chazy basin, was a subsiding trough which repeatedly was submerged beneath sea level during the early Paleozoic and received marine deposits, whose uneroded remnants still lie in comparatively undisturbed condition where they were deposited. In one or more troughs which lay farther to the east and were mostly quite separate from the Chazy basin, early Paleozoic deposits were also formed. These have since been greatly folded and faulted, and bodily overthrust to the west from their original position, upon the rocks of the Chazy basin. For convenience we here refer to them as the deposits of the eastern trough, without thereby meaning in any way to indicate that we necessarily regard them as deposits of an original single trough, rather than as of more than one. These rocks do not now lie where they were originally deposited and they are much more disturbed and folded than the rocks of the western trough.

The formations of the western trough, in order of age, are the Potsdam sandstone, Theresa formation, Hoyt limestone, Little Falls dolomite, Black River limestones (chiefly the Amsterdam limestone), basal Trenton shale and limestone (Glens Falls limestone) and Canajoharie shale. All these, with the exception of the Trenton shale and limestone, appear upon the map.

Surface upon which the western basin rocks were deposited. The old surface of Precambric rocks, upon which the basal portion of the Paleozoic deposits rests in New York, has been shown by several observers to be an uneven surface, but yet not excessively uneven. The data are most easily obtainable on the west, since there the rocks are much less disturbed than on the east. On the southwest both Miller and Cushing have shown that this surface was exceedingly smooth, almost plane, with only a few scattered hillocks rising a few feet above the general level.[1] None have been observed rising higher than 50 feet above this level. On the northwest this surface is far less smooth, and consists of rapidly alternating elevations and depressions, with maximum differences of some 125 feet of altitude. The surface consists chiefly of slopes, and but little of it is flat.[2]

On the southeast, in the Saratoga region, the surface seems much as on the northwest. For the Broadalbin quadrangle Miller reports

[1] N. Y. State Mus. Bul. 126, p. 35; N. Y. State Mus. Bul. 77, p. 59-62.
[2] N. Y. State Mus. Bul. 145, p. 54-60.

similar results.[1] Contacts are few on the Saratoga quadrangle, but to the north of the village the basal Potsdam conditions are well shown for a distance of 4 miles along the Potsdam margin; and for a mile along the Hudson just below Corinth exposures of this horizon are excellent. The Precambric surface on which the Potsdam rests is irregular. The more resistant bands of the Grenville and the igneous rocks stand above the mean level, as hillocks or ridges, while the weaker rocks are worn away to valleys or basins below mean level. Potsdam deposition began in the depressions, and as the sand accumulated it finally overtopped the elevations. There are differences of level of at least 75 feet, and probably more.

Assuming that the conditions of this surface on the northwest and the southeast (Thousand Islands and Saratoga regions) are substantially the same, as the evidence indicates, and that the surface on the southwest (Little Falls–Remsen) is much smoother, it would seem probable that in the opposite direction, on the northeast, it should be rougher. In that direction we lack the detailed work which might render the matter certain and can merely state that the impression given us by our reconnaissance work on the northeast is that it *is* rougher. We have seen Precambric hills which project up into the Potsdam to the distance of 200 feet. From the data at hand we therefore conclude that the Precambric surface under the Potsdam is least smooth on the northeast (Clinton county), and that it steadily increases in smoothness toward the southwest. The northwest and the southeast are about equidistant from these and should be expected to show about equal character of surface, as they do.

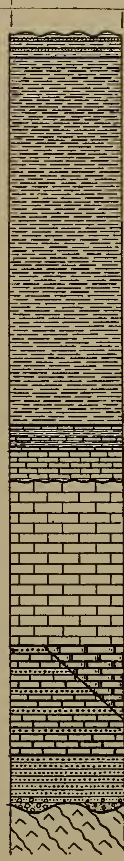
CAMBRIC PERIOD

General statement. The formations of Cambric age belonging to the western basin and found within the mapped district, are the Potsdam, Theresa and Little Falls formations, the Potsdam a sandstone, the Theresa a series of passage beds of alternating sandstone and limestone or dolomite, and the Little Falls a dolomite formation. Between the Theresa and Little Falls in the near vicinity of Saratoga is a more calcareous formation which we call the Hoyt limestone, which is probably best regarded as an upper member of the Theresa formation.

According to prevailing present-day classification, these formations are of Upper Cambric age. They also belong in the new system, Ozarkic, which Ulrich is proposing to establish between

[1] N. Y. State Mus. Bul. 153, p. 50–52.

the Cambric and Ordovicic of former classifications. Whether the Ozarkic is ultimately given the rank of a system or is regarded simply as a series forming the uppermost division of the Cambric, does not concern us here; but rather the fact that the above-listed formations are of Ozarkic age.



System	Formation	Symbol	Thickness	Character of formation
Ordovicic	Schenectady formation	Cs		Black and gray shales, grit and sandstone
	Canajoharie formation	Oc	700[1] +	Black shales of lower Trenton age; in part soft, in part hard and slaty
	Glens Falls formation		50′	Alternating black shale and thin black limestone
	Amsterdam formation	Oa	50[1]	Blue, fossiliferous limestone
Cambric	Little Falls formation	Cl	300—400[1]	Massive, irregularly bedded dolomite, dark to light gray color
		Ch	100[1]	Hoyt limestone member. Dolomite and limestone with black oolite
	Theresa formation	Ct	50[1]	Alternating sandstone and dolomite
	Potsdam formation	Cp	50—150[1]	Coarse sandstone with basal conglomerate
	Precambric			

Fig. 3 Generalized columnar section of the rocks of the Saratoga quadrangle, and of the western portion of the Schuylerville quadrangle.

POTSDAM SANDSTONE

After an enormously long period of existence as a land area, whose duration comprised all the latter portion of Precambric time and most of the Cambric as well, and whose history is recorded in erosion of the Precambric rocks, the eastern margin of the Adirondacks became depressed and deposits commenced to accumulate upon its surface. Thus began the formation of the Potsdam sandstone.

The deposit began on the northeast and extended both west and south, accumulating in sinking troughs along the line of the Champlain and St Lawrence valleys. It is thickest in Clinton county, where the thickness is an unknown amount in excess of 1000 feet and where the lower beds are unlike those shown elsewhere. These beds are coarse conglomerates, feldspathic sandstones and ferruginous, shaly sandstones, wholly without fossils and apparently deposited above sea level. They are followed above by purer, quartz sandstones, white, gray, yellow, brown or red in color, mostly very thoroughly cemented and resistant rocks. Above come less firm, somewhat calcareous sandstones, forming the upper part of the formation. In this upper division and in the upper part of the preceding division a scant fauna appears which shows that this portion of the formation is marine.

It is only this upper division of the formation which is found in Saratoga county. The thickness here does not average in excess of 100 feet, ranging from 50 to 150 feet, the variations being chiefly due to the irregularity of the Precambric surface upon which it was deposited. There is usually found a few feet of basal conglomerate, seldom very coarse, above which the formation is unbroken sandstone, the lower half siliceous, the upper calcareous, in which many of the beds weather to an ochreous rotten stone. No fossils were seen by us in the formation on the Saratoga quadrangle, though Miller found Lingulepis acuminata in it on the adjacent Broadalbin quadrangle.

About Saratoga the most extensive exposures of the formation are those north of the village in Greenfield township. It is also thinly exposed at Corinth. The best continuous section is exposed along a small branch of Glowegee creek, a mile south of East Galway. At the base of the section the creek cuts down into the Precambric, exposing a small outlier of this formation. Above this a continuous section 200 feet thick is exposed. The lower 50 feet is chiefly sandstone, with occasional beds of calcareous sandstone; in the next 50 feet sandstone and calcareous sandstone alternate, with an occasional bed of blue, sandy dolomite in addition. The upper 100 feet consists of alternations of all three. This we definitely assign to the Theresa formation. The lower 100 feet we assign to the Potsdam, notwithstanding the presence of an occasional dolomite bed. There is never any sharp boundary between the two formations.

THERESA FORMATION

Everywhere in New York where the Potsdam sandstone occurs, it is united with the formation next above, usually a dolomite formation, by a series of intermediate or passage beds which consist of alternating sandstone, calcareous sandstone and dolomite. These passage beds differ from the sandstone beneath and the dolomite above, are sufficiently thick to require mapping as a separate formation, as such require a name, and we are calling them the Theresa formation.[1] The sandstone is in excess in the lower part of the formation, and the dolomite in the upper. Deposition was apparently continuous but physical conditions slowly changed, the sand supply from the Adirondack land slowly diminishing and finally being entirely cut off. Because of this it is impossible sharply to delimit the formation, either at base or summit. In what we here class as upper Potsdam there is an occasional bed of dolomite, and a few stray beds of sandstone run well up into the overlying dolomite formation. Nevertheless there is a sufficient thickness of mingled sandstone and dolomite, about which there could be no possible difference of opinion, to justify its separateness as a formation.

In the general region the Theresa formation has a thickness of from 150 to 200 feet. Thus Miller gives its thickness as 200 feet on the Broadalbin quadrangle, while our measured sections at Whitehall and at Ticonderoga show a thickness of at least 150 feet. There is at least 150 feet of it in the section south of East Galway, on the Saratoga quadrangle, and the full thickness is not there exposed. In all these localities the formation consists of alternating beds of hard, vitreous sandstone, weak calcareous sandstone and sandy blue dolomite, with *Lingulella acuminata* as its most abundant and characteristic fossil.

West and northwest of Saratoga, in Greenfield township, the section differs. Instead of a thickness of 150 to 200 feet, the

[1] N. Y. State Mus. Bul. 145, p. 64–66.

Theresa formation is only 50 to 75 feet thick and is overlaid by a limestone formation, some 100 feet thick, which contains but little interbedded sandstone and is quite fossiliferous. This seems to us on the horizon of the upper portion of the Theresa of the sections north and west, and we therefore classify it as a member of the Theresa formation.

The rock cuts along the Adirondack Railroad, northwest of Saratoga, together with quarries to the south of the railroad, furnish us with the best section of this phase of the Theresa formation and of the Potsdam beneath. The section has already been published, and is here reproduced.[1]

	FEET	INCHES
22 Rocks concealed between two railroad cuts; boundary between Theresa and Hoyt limestone member in the interval; thickness about	20	....
21 Rotten, brown, calcareous sandstone; blue when fresh	....	8
20 Hard, vitreous, light colored sandstone, banded with narrow streaks of darker, calcareous sandstone	2	4
19 Thin bedded, blue, calcareous sandstone, weathering brownish	....	9
18 Blue black, oolitic dolomite, frequent rounded quartz grains, many small drusy cavities	1	3
17 Blue, calcareous sandstone, weathering light colored, upper portion shaly	1	8
16 Hard, light colored, vitreous sandstone	1	6
15 Thin bedded, calcareous sandstone, somewhat oolitic, blue when fresh but rapidly weathering brown, mottled and crumbly, many drusy cavities with calcite and quartz crystals; abundant trilobite fragments, the lowest zone of these so far discovered in the Saratoga region	1	3
14 Light colored, vitreous sandstone	2	5
13 Bluish, nodular, finely crystalline dolomite, with a slight amount of calcite cement, shaly at base and summit, frequent nodules of crystalline calcite; holds Lingulepis acuminata	2	3

[1] N. Y. State Mus. Bul. 140, p. 111–12.

Plate 1

H. P. Cushing, photo, 1910

Alternating sandstone and dolomite of Theresa formation in railroad cut, 3 miles west-northwest of Saratoga. The outstretched hand is resting on the trilobite layer, no. 15 of the section. Beds 12 to 17 are shown in the view.

	FEET	INCHES
12 Light colored, vitreous sandstone	1	3
11 Gray, banded sandstone, slightly calcareous	3	9
10 Alternating calcareous sandstone and crystalline dolomite of blue gray color, large nodules of crystalline calcite in the latter; base of cut	3	....
9 Concealed between this and next cut east; arbitrary boundary between Theresa and Potsdam in the interval; about	30	....
8 Hard, vitreous, light colored sandstone with darker calcareous sandstone above and below	1	8
7 Concealed to brook exposures next east; about	30	....
6 Light colored, vitreous sandstone, with alternating layers of darker, calcareous sandstone which weather rapidly	30	....
5 Light colored, vitreous sandstone	15	....
4 Concealed	4	....
3 Light colored, vitreous sandstone	2	....
2 Concealed	4	....
1 Conglomerate, increasing in coarseness downward and reaching nearly to base of formation	10	....

Numbers 1 to 8 are regarded as constituting the Potsdam though there is some question about the classification of 7 and 8, which may be Theresa. If they are regarded as Potsdam, that formation has a thickness of 96 feet, 8 inches in the section, with the base not reached, though it can not be more than a few feet away. Above is a thickness of 52 feet of beds which are certainly to be classed as Theresa, and occasional beds of sandstone run still higher.

The State road out of Saratoga toward Corinth crosses the Adirondack Railroad in a low depression between two rock cuts. The easterly one of these is the one in which the upper part of the above section was measured, nos. 10 to 21. It is the most accessible locality within the district about Saratoga where the Theresa formation is well shown. A photograph of the rock wall of the cut is shown in plate 1, the extended hand resting on the fossiliferous layer, no. 15 of the section. From this we obtained species of Ptychoparia and Agraulos which are specifically different from the forms found in the Hoyt limestone above. The species collected here were, in addition to L i n g u l e l l a

(Lingulepis) acuminata, Agraulos sp. nov.[1] and Ptychoparia matheri Walcott.

HOYT LIMESTONE MEMBER

In 1879 Dr C. D. Walcott first described an Upper Cambric fauna from limestones of that age in the vicinity of Saratoga, and made frequent reference to the same fauna and beds in subsequent publications.[2] In 1899 Clarke and Schuchert first assigned a name to this formation, calling it the Greenfield limestone.[3] This name, however, was preoccupied having been previously assigned to a limestone of Siluric (Monroe) age, in central Ohio. A new name had therefore to be assigned, and yet no suitable one seemed forthcoming. The known exposures of the formation are all in Greenfield township, and the villages in the township all bear the name of Greenfield, in so far as they are located on the formation. There are no good exposures of the formation along any watercourse whose name could be utilized. The name Saratogan was preoccupied. Under the circumstances there seemed no alternative but to apply to the formation the name of the quarry at which it is best and most fully shown (plate 2). The name of the quarry has already appeared in geologic literature, in papers by Hall, Walcott and Prosser.[4] Unfortunately the farm has changed hands and the quarry is no longer locally known as the Hoyt quarry. But no other name suggests itself as suitable, and we are therefore proposing the name Hoyt limestone for the formation, at the same time indicating the location of the quarry upon the geologic map.

In an earlier paper by Ulrich and Cushing this Hoyt limestone was made a basal member of the Little Falls dolomite, the next formation above.[5] More strictly, however, it seems a phase of the upper portion of the Theresa formation, the thickness of the Theresa and Hoyt together, in the vicinity of Saratoga, about equaling the thickness of the Theresa alone north and west of Saratoga;

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[1] Regarding this Dr C. D. Walcott writes Doctor Ruedemann this form is "very closely related, if not identical with a species of Agraulos which I have marked as a new species from the upper beds of the St Croix sandstone of Wisconsin."

[2] N. Y. State Mus. Nat. Hist. 32d Ann. Rep't, p. 129–31; U. S. Geol. Surv. Bul. 81, p. 346–47.

[3] Science, December 15, 1899.

[4] N. Y. State Mus. Nat. Hist. 36th Ann. Rep't, pl. 6, description; Science, 1884, 3:137; N. Y. State Mus. Bul. 34, p. 478–79.

[5] N. Y. State Mus. Bul. 140, p. 129.

Plate 2

H. P. Cushing, photo, 1910

Hoyt limestone at Hoyt quarry, showing the lower 16 feet of the 25 feet of the quarry section. The massive central bed, nearly 5 feet thick, is noteworthy.

while the Little Falls dolomite at Saratoga has about the same thickness as it has to the west and north. Miller has already made a similar suggestion.[1]

The Hoyt limestone is composed of alternating beds of dolomite and of limestone, and is comparatively thick bedded. The color is usually dark and often black. Several beds of black oolite occur, chiefly in the lower portion of the formation. Many of the limestone beds furnish abundant fossils, chiefly trilobites in very fragmentary condition. Along with these are small gastropods, which are much less abundant. Lingulella acuminata occurs everywhere. Perhaps the most striking fossils of the formation are the big, reeflike masses of the organism of unknown nature, known as Cryptozoon. The genus was originally described by Hall from the exposures by the roadside just north of the Hoyt quarry (plates 3 and 4), where a bared and glaciated surface of the rock is splendidly exposed over a considerable area. Reefs and masses of more than one species of this genus are of common occurrence in both the Hoyt limestone and the overlying Little Falls dolomite, in the latter ranging throughout the Mohawk and Champlain valleys. The reeflike nature of the masses is well shown in many places in the district, notably so perhaps in the railroad cut just east of Greenfield depot. Midway of this cut is shown a Cryptozoon reef of massive limestone (6 feet thick). Toward the west this bed breaks up into thinner bedded material which at the same time becomes very sandy and with layers of nearly pure quartz sand, while to the east it remains pure limestone, though the Cryptozoon gives out. The east is taken to be the seaward and the west the landward side of the old reef.

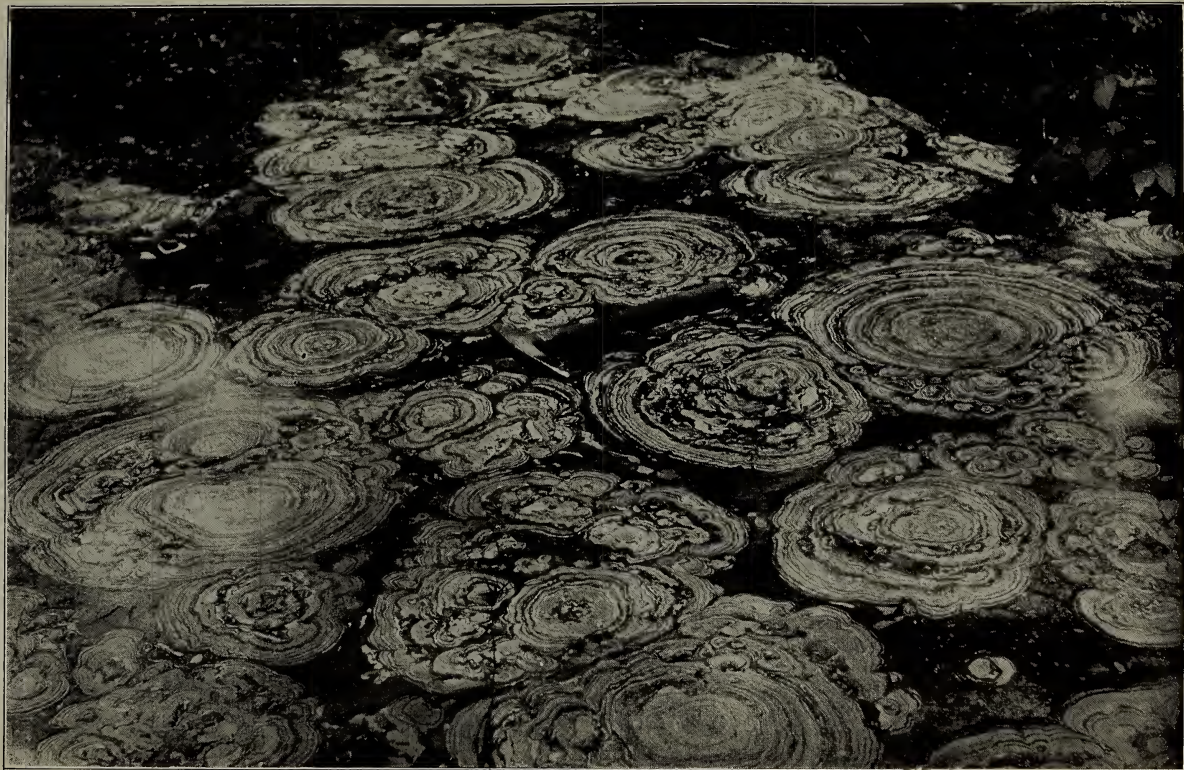
The Hoyt limestone is well shown in the so-called railroad quarry, 1 mile north of Saratoga (plates 5 and 6). But neither base nor summit shows there and the outcrop is an isolated one lying between two branches of a fault, so that it tells nothing whatever in regard to the stratigraphic relations of the formation. It has a local high dip to the southwest due to proximity to a fault, shows a thickness of some 20 feet of the formation including a splendid Cryptozoon reef, and is an excellent locality for fossils. But for the stratigraphy we must go to the exposures in the railroad cuts and the vicinity of the Hoyt quarry. Here an excellent section of the greater part of the formation is obtained, overlying the Theresa formation, hence making certain its stratigraphic position. The summit, however, is not seen, though if we are correct in

[1] N. Y. State Mus. Bul. 153, p. 30.

assigning the exposures at the crossroads at South Greenfield to the base of the Little Falls dolomite, then the section closes in beds not far from the top. The section has already been published and is here repeated, numbered in continuation of the Theresa section already given.

	FEET	INCHES
40 Exposures at Hoyt quarry: hard, blue to black, subcrystalline to crystalline magnesian limestone, largely of dolomite rhombs with calcite cement; 1 foot from the top is a Cryptozoon reef bed, and the section rests on another such bed, which is the same as the one shown by the roadside (plates 3 and 4); the rock is partly thin and partly thick bedded; some of the layers show coarsely crystalline calcite cement, giving large glittering cleavage faces on freshly broken surfaces; trilobites, gastropods and Lingulella are found throughout........................	25	....
One-third of a mile north of the Hoyt quarry is another quarry face by the roadside, capped by the same Cryptozoon layer which forms the base of the Hoyt quarry section, but was not included in the 25 feet of that section.		
39 Dark blue, subcrystalline, magnesian limestone full of Cryptozoon; frequent black, oolitic grains	1	5
38 Massive beds of blue, finely crystalline, magnesian limestone, with occasional sand grains; trilobite fragments	5	5
37 Thin bed of calcareous sandstone, weathering to brown, rotten stone..........................	....	5
36 Two beds of dark blue, crystalline, magnesian limestone with some sand grains..............	2	5
35 Layer of dark gray, calcareous sandstone.........	1	7
34 Light colored, vitreous sandstone with films of darker, calcareous material..................	1	3
33 Dark colored sandstone with calcareous cement...	....	4
Four-tenths of a mile northeast of this are two considerable cuts along the railroad in which the following section is shown (plate 7). The hiatus is estimated at.........................	20	....

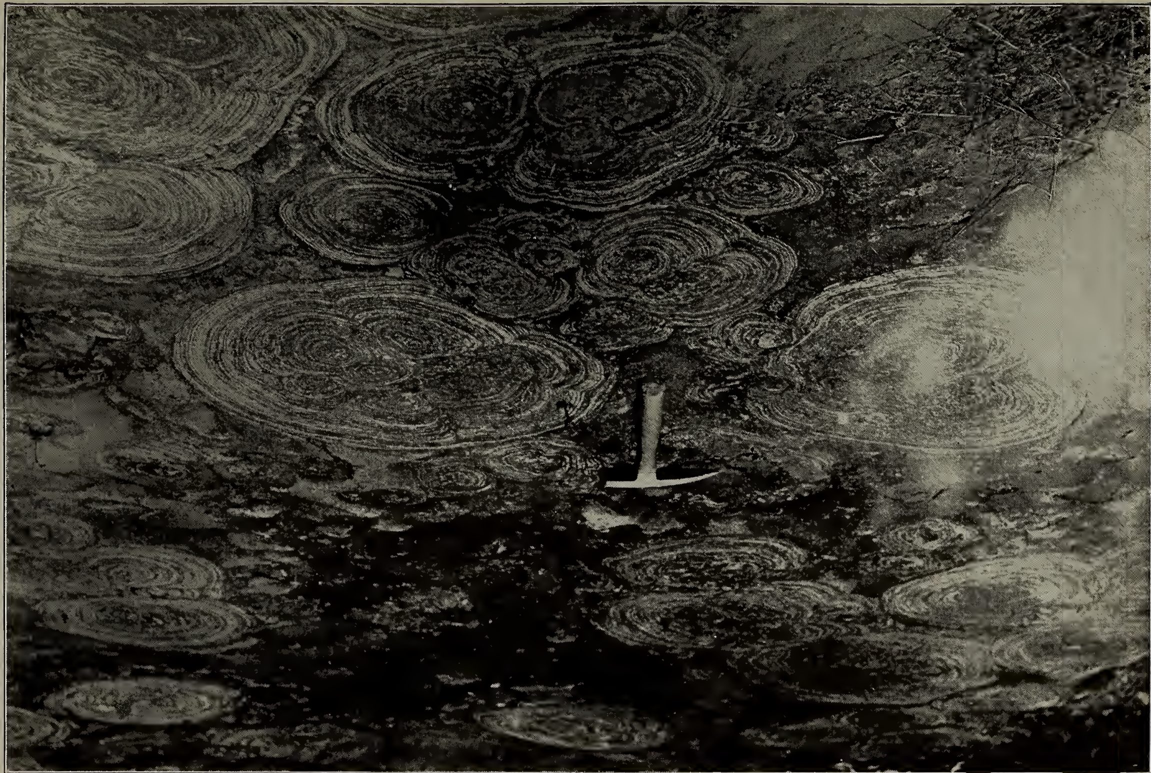
Plate 3



H. P. Cushing, photo, 1910

Cryptozoon proliferum Hall. Glaciated exposure of one of the Cryptozoon reef beds of the Hoyt limestone, by the roadside near the Hoyt quarry. Original locality of Hall's figure of the species.

Plate 4



H. P. Cushing, photo, 1910

Another view of the Cryptozoon surface, same locality. Both views show foreshortening due to down-pointing of the camera.

	FEET	INCHES
32 Dark blue, subcrystalline, magnesian limestone....	1	3
31 Blackish, oolitic dolomite......................	1	8
30 Dark blue, crystalline dolomite, calcite cement which shows large cleavage faces; holds Lingulepis acuminata	....	10
29 Black, oolitic dolomite containing pebbles of mud limestone	1	8
28 Rotten, crystalline dolomite, calcite cement rapidly leaching out	....	5
27 Blackish, oolitic dolomite in three beds, the upper a Cryptozoon bed; frequent sand grains and many drusy cavities with quartz and calcite crystals	2	6
26 Easily rotting crystalline dolomite, calcite cement, very shaly above..............................	....	9
25 Hard, light colored, vitreous sandstone...........	1	4
24 Crystalline bluish dolomite, calcite cement........	1	7
23 Two massive beds of blackish, subcrystalline magnesian limestone, with frequent sand grains.....	4	3
22 Concealed between the two railroad cuts; boundary between Hoyt limestone and Theresa formation in the interval..............................	20	....
	94	1

Several points brought out by this section need to be noted. Vitreous sandstones run up in it for nearly 60 feet above the base, and there may be some question in regard to the classification of this portion of the section. The sandstones are not so numerous as in corresponding portions of the Theresa section elsewhere; the black oolitic and magnesian limestone beds are quite characteristic of the Hoyt, and not so much so of the normal Theresa. The section brings out clearly the fact that the Hoyt lies above the Theresa passage beds and is followed by the Little Falls and that the same interval elsewhere is occupied by a thickness of passage beds equal to the combined thickness of the Hoyt and Theresa of the Saratoga section. In other words, the Hoyt is a local phase of the upper Theresa, probably a more offshore phase. It is exposed only at Saratoga because only here has erosion cut down to this phase. Elsewhere the near shore phase of the formation is exposed and the extension of the Hoyt lies to the east and south of Saratoga, buried from sight beneath the younger rocks which cover it in those directions. The waters were clearer, less subject to incursions of sand, Cryptozoon reefs flourished as they did not in the normal Theresa, and trilobites and gastropods lived on the surface of the reefs, where we find their fossil remains abundantly today.

To the thickness of the Hoyt limestone as here measured there needs to be added an unknown amount which we estimate as probably not over 25 feet, in order to reach the summit of the formation.

From the Hoyt limestone we collected the following fauna: Cryptozoon proliferum, Lingulella (Lingulepis) acuminata, Triblidium cornutaforme, Matherella saratogensis, (Murchisonia) sp. indet., Matthewia variabilis, Pelagiella hoyti, P. minutissima, Agraulos saratogensis, Lonchocephalus calciferus, Dicellocephalus hartti, D. tribulis.

LITTLE FALLS DOLOMITE

General statement. The name "Calciferous" was originally applied to the considerable thickness of dolomitic rocks which overlies the Potsdam sandstone in the Champlain and Mohawk valleys. Later on Clarke and Schuchert replaced this by the name Beekmantown, and to the rather unfossiliferous phase of the formation in the Mohawk valley gave the local name of Little Falls dolomite. Brainard and Seely were the first carefully to measure and subdivide the formation in the Champlain valley, making five subdivisions which they lettered from A to E.[1] Recent work of Ulrich, Ruedemann and Cushing showed that the Little Falls dolomite of the Mohawk valley was the equivalent of division A and the lower part of division B of the Champlain Beekmantown, and that divisions C, D and E were absent along the Mohawk; furthermore that an unconformity everywhere separated the Little Falls from the overlying Beekmantown, and that the natural affiliations of the former were with the Potsdam and Theresa beneath, rather than with the Beekmantown above, both structurally and faunally.[2] In the Saratoga region the Little Falls is present and the Beekmantown wholly absent. The lowest division of the Beekmantown,

[1] Am. Mus. Nat. Hist. Bul. 3, p. 1.

[2] N. Y. State Mus. Bul. 140, p. 97–140.

Plate 5

H. P. Cushing, photo, 1910

Railroad quarry in Hoyt limestone, 1 mile north of Saratoga, looking northeast, showing the railroad cut and the quarry to the west. The beds are the same as those at the Hoyt quarry.

Plate 6

H. P. Cushing, photo, 1910

North end of the quarry shown in plate 5, looking northwest and showing the strong southwesterly dip.

the Tribes Hill limestone, may have been deposited here and later removed by erosion. The remainder of the Beekmantown was probably never deposited about Saratoga or along the Mohawk.

Description. The Little Falls dolomite is composed chiefly of rather massive beds of gray dolomite. The larger part of the formation consists of dark gray, fine grained beds. Many of these contain some calcite, chiefly as a cement binding the dolomite crystals together. On weathered surfaces the dolomite is the more resistent of the two, the calcite is dissolved, leaving somewhat projecting dolomite crystals and giving a porous, sandy appearance to the weathered surface. Beds of this type are best exposed along North Broadway as the road climbs the hill south of St Clements.

In addition there is a considerable thickness of more coarsely crystalline, lighter colored dolomite in the formation. About Saratoga such beds form the summit of the formation and are exposed in many places, perhaps best in the Maple Avenue quarry. They are, in general, quite pure dolomite, lacking the calcite cement which occurs so generally in the darker beds (plate 8).

It is impossible to get any very correct idea of the thickness of the Little Falls dolomite, from the exposures of the quadrangle. There is not sufficient variation in the character of the rock to enable one to assign the beds of the scattered exposures to their proper horizon in the formation; and faults so abound that nothing like a continuous section of the entire formation exists in the region. At Saratoga Springs the exposures are in a triangular fault block, and the exposed thickness is 119 feet.[1] This is the upper portion of the formation and gives no clue to the amount beneath which is lacking. Two deep wells have been drilled at Saratoga with the diamond drill, with careful preservation of the drill cores, one at the Congress and the other at the Hathorn spring. We have had the opportunity to study the former, though we have unfortunately not been able to see the latter. Each well went down near the Saratoga fault, and each must rest under the suspicion of having crossed a small branch of the fault in such way as to duplicate part of the well section and increase the apparent thickness. In the Congress well 18 feet, 2 inches of drift was passed through, then 18 feet, 7 inches of Amsterdam limestone, after which the entire core of the well, some 281 feet, consisted of Little Falls dolomite. The upper 40 feet of this was of the characteristic coarsely crystalline, light colored dolomite which forms the upper part of the formation about

[1] N. Y. State Mus. Bul. 140, p. 108–9.

Saratoga. Beneath this was 180 feet of darker colored dolomite of varying grain, the upper and lower portions through a thickness of some 50 feet each coarser than the center. The upper part had many nodules of crystalline calcite. Underneath this was a recurrence of coarse, light colored beds. This gave rise to the suspicion that perhaps a fault was crossed here causing a reappearance of the upper beds of the formation. But no suggestion of a fault was given in the appearance of the drill core, and a careful comparison of this portion with the upper portion did not show any exact correspondence. There was also a greater thickness of the coarse beds here than above. Below, dark beds came in again and the well terminated in these. If this section is really unbroken, then the thickness of the formation is certainly 300 feet and may be considerably more.

The Hathorn well was 1006 feet deep. After 62 feet of drift the drill entered the Amsterdam limestone. The bottom 231 feet were reported as Potsdam, but the thickness suggests that the Theresa is also included and perhaps the basal Hoyt. Assuming it to represent Potsdam and Theresa, and deducting this thickness and the drift thickness from the total of the well, leaves yet a thickness of over 700 feet for the combined Amsterdam, Little Falls and Hoyt formations. If the bore does not cross a fault this would mean a thickness of from 500 to 550 feet for the Little Falls which is considerably in excess of any known thickness elsewhere possessed by the formation. It is doubtful if it exceeds 350 feet in the Saratoga region, though it may reach 400, which is as great a thickness as it is known to reach at any point.

There is much chert in the formation. Black chert is the most abundant but gray chert is by no means uncommon. The upper beds of the formation are heavily charged with chert in nearly all localities throughout its extent, and Saratoga is no exception to the general rule. The upper bed at the Maple Avenue quarry is full of chert. The lower beds of the formation are also heavily charged with it. These beds are best seen about a mile south of Porter Corners.

The formation is everywhere exceedingly unfossiliferous. Lingulella acuminata is occasionally found in the lower beds, and a few fossils are sometimes to be seen in the upper cherts. The most common fossil, however, is Cryptozoon, reefs of which occur throughout the formation. This is the only fossil which we have seen in the formation about Saratoga. In most of the formation the

Plate 7

Potsdam sandstone in 3″ cut on Adirondack R. R

Plate 8

H. P. Cushing, photo, 1910

Upper beds of Little Falls dolomite in cliff back of High Rock spring, Saratoga. The cliff face is the fault scarp of the upthrow side of the Saratoga fault.

Cryptozoon is C. p r o l i f e r u m, but in the upper beds another and quite different species comes in. A bed of dove limestone which occurs capping the upper, light colored dolomite to the west of Saratoga, exposes this Cryptozoon most excellently (plates 9 and 10). The same species occurs at the summit of the formation at Ticonderoga and elsewhere. The summit beds are usually full of chert and the Cryptozoon is often heavily silicified.

Unconformity at the summit of the Little Falls. The Little Falls dolomite is directly overlaid, in the Saratoga region, by the Amsterdam limestone of upper Black River age. No representatives of the Beekmantown and Chazy groups appear in the section, and the lower beds of the Black River group are also lacking. The Tribes Hill limestone, which overlies the Little Falls in the Mohawk valley and is of probable lowest Beekmantown age, is absent about Saratoga. It may have been thinly deposited and subsequently eroded. It seems quite safe to say that the Beekmantown and Chazy deposits never reached the district, and that the lower Black River rocks were laid down but thinly if at all.

Aside from the absence of these rocks from the region, the physical evidence of the unconformity is twofold. The base of the Amsterdam rests on quite different beds of the Little Falls, at the various exposures of the contact, indicating erosion of the surface prior to Amsterdam deposit; and the basal bed of the Amsterdam varies from place to place, showing that the surface upon which it was laid down was irregular and that the lower beds of the Amsterdam are only found in the old depressions. Furthermore the Amsterdam begins with a basal conglomerate full of Little Falls pebbles. This basal layer is best seen at Saratoga. In the northern part of the village, just west of the fault line and just north of where the Delaware & Hudson Railroad crosses the fault, thin patches of this conglomerate may be seen resting on the upper surface of the Little Falls, proving that it is the very top of that formation which there forms the upthrow face of the fault.

AMSTERDAM LIMESTONE

In the sections of the eastern Mohawk region there appears, beneath the rocks which are strictly referable to the Trenton group, a thin limestone formation which is wholly distinct from anything found in the vicinity of Trenton Falls and which we regard as an upper member of the Black River group and are calling the Amsterdam limestone. A detailed account of the formation in the type region has not yet been published, but it is hoped that it will soon appear. A preliminary statement concerning it has already been made.[1]

Within the Saratoga quadrangle this limestone is seldom exposed, owing to heavy covering of glacial drift. The best and most complete section of it is at Rock City Falls, where the contact with the underlying Little Falls dolomite is exposed. At Saratoga the base is thinly exposed and a wedge of the formation is infaulted along the Saratoga fault, exposed back of the Star spring and for a short distance northward. There is a good exposure at Rowlands mill, which, however, does not show the base; and there are other exposures through North Milton, the best folded into a little syncline. There is also a small exposure of basal Amsterdam and summit Little Falls, drop-faulted along the West Galway fault, south of East Galway. Nowhere within the quadrangle has the summit been seen exposed, except perhaps at Rowlands mill.

The best section and the one exposing the lowest beds, is that at Rock City Falls (plate 11). The section here had been previously measured by Prosser.[2] There is some 14 feet of Little Falls dolomite in the face of the fall, gray, finely crystalline dolomite for the most part, full of black seams, occasional nodules of crystalline calcite, and with much chert midway. The horizon seems beneath that of the coarser, light colored beds, such as form the summit about Saratoga, and they have likely been removed by erosion. The contact shows slight irregularity, as it does at Saratoga. The lower 3 feet of the overlying beds have a look of the Lowville and were referred to that formation by Prosser. We collected some fossils from them, however, which seemed to belong to the Amsterdam, though we are somewhat in doubt in the matter. If this be Lowville it is the only occurrence of this formation seen within the quadrangle limits. Above follow 38 feet of Amsterdam, somewhat thin-bedded, crystalline fossiliferous limestone of blue color. Not only are the Lowville-looking beds absent elsewhere but the succeeding 15 feet is also absent in the North Milton sections, the higher beds resting directly on the Little Falls there. At Rowlands mill and in the North Milton sections the summit shown is thinner bedded and likely above anything in the Rock City Falls section. About North Milton are a half dozen exposures, chiefly pinched into a little syncline with the upper Little Falls, as shown on the areal map.

[1] Am. Jour. Sci., 31:143.

[2] N. Y. State Mus. Bul. 34, p. 476.

Plate 9

H. P. Cushing, photo, 1911

Glaciated surface of Cryptozoon at summit of Little Falls dolomite, 4 miles west of Saratoga. This is a different species from the C. proliferum shown in plates 3 and 4 and is a characteristic form in the upper Little Falls dolomite.

Plate 10

H. P. Cushing, photo, 1911.

Another portion of the Cryptozoon reef shown in plate 10; in the background appears the exposure shown in the previous view; the picture was taken just after a shower and the dark patch is a portion of the surface that had not yet dried.

Since the actual summit nowhere shows, we are somewhat in doubt as to the actual thickness of the formation and as to what directly overlies. The many drilled wells to the south of Saratoga aid in supplying the information. Underneath the Canajoharie shale these wells show an average thickness of from 40 to 45 feet of alternating shale and limestone, beneath which comes 35 to 40 feet of limestone and then the Little Falls. The limestone is Amsterdam. Whether any of the alternating shale and limestone is also to be classed as Amsterdam we do not know. We have seen but one exposure of the horizon, in a cut by the roadside a mile east of Rock City Falls, an exposure so poor as really not to merit the name. The fauna was Trenton, not Amsterdam; but the exposure may not have been basal. We incline to the opinion that this alternating shale and limestone is all Trenton, and that the thickness of the Amsterdam is from 40 to 60 feet, varying with the irregularity of the floor on which it was deposited.

The appended list of the more common fossils of the Amsterdam we owe to the courtesy of Dr E. O. Ulrich:

Solenopora compacta
Stictoporella cribrosa
Rhinidictya mutabilis
Phyllodictya varia
Eridotrypa minor
Arthroclema pulchellum?
Pachydictya acuta var.
Columnaria halli
Strophomena trentonensis
Dalmanella rogata
Dinorthis pectinella
Bathyurus spiniger
Leperditia n. sp.

GLENS FALLS (BASAL TRENTON) LIMESTONE

The zone of alternating shale and limestone, some 40 feet thick, which overlies the Amsterdam in the well sections and which is not exposed at the surface, is the only zone in the district to which the term Trenton limestone could at all properly be applied, and there is even question as to its propriety here since the shale exceeds the limestone. Outcrops on the Broadalbin quadrangle and in the eastern Mohawk valley, where the sections are exceedingly like those about Saratoga, leave little doubt that this zone is of lower Trenton age. On the Broadalbin quadrangle Miller has mapped this zone with the Amsterdam, and separate from the overlying Canajoharie shale. The Canajoharie shale, however, is of Trenton age, and it seems to us more fitting to group the basal zone which contains the thin limestone bands with this, as its basal portion, rather than with the Amsterdam, which we regard as of Black

River age. Ruedemann has termed this limestone the *Glens Falls limestone,* since its fauna has shown it to lie below beds of the Trenton Falls section.[1]

THE CANAJOHARIE SHALE

BY R. RUEDEMANN

The Canajoharie shale is the surface rock in the southernmost area of the Saratoga quadrangle and thence extends northeast, occupying the area between the Snake Hill formation of the eastern trough and the McGregor fault and its branches. West of Saratoga it rests directly on the basal or Glens Falls limestone and southward the formation strikes toward the Mohawk river near which it passes under the Schenectady beds. Northward from the Schuylerville quadrangle it has not been traced beyond Glens Falls, the constituent divisions of the shale belt north of the Hudson valley having not yet been differentiated.

This formation, which is most typically developed in the Mohawk valley, has been fully described by the writer in Bulletin 162. It consists almost entirely of soft black, carbonaceous, more or less calcareous, argillaceous shales and is therefore quite distinct in its lithologic characters from the Normanskill-Snake Hill group, although where it has become involved in the folding, as in Albany county, it may through cleavage and slickensided slip planes become quite similar to some of the darker shales of the latter formations. It lacks, however, the smooth, lighter colored, gray, greenish and bluish purely argillaceous shales so prevalent in them, and the black Canajoharie shale weathers a characteristic light drab, like the Utica shale, while the dark shales of the Normanskill-Snake Hill weather grayish brown or spotted or whitish when somewhat siliceous. Nor does the Canajoharie contain any trace of the white weathering chert beds and grit of the shales of the eastern trough. A sandstone bed 2 to 3 feet thick was observed in only one case in the Snook kill below Gansevoort, although thinner layers of somewhat sandy shale are sometimes met with. On the other hand there frequently occur harder, bluish gray mud beds indurated by calcite which are mostly 3 to 6 inches but sometimes 3 to 4 feet thick, as in the bank of the Kayaderosseras creek above Ballston Spa. These mud beds break conchoidal or lumpy and are very fine grained. The shale is fissile and splintery

[1] N. Y. State Mus. Bul. 162, p. 22.

for the most part. Its uniform, carbonaceous, fine grained character is the most distinguishing feature of the formation.

Much of the shale contains pyrite which, becoming oxydized, fills the cleavage and bedding planes in some places with rusty brown films and produces efflorescences of alum salts on the protected walls of cliffs, as about Ballston Spa, and is probably also responsible for the occurrence of sulphuretted hydrogen in some of the springs. In some cases the graptolites were found very well preserved in pyrite.

These shales are flat on the two quadrangles here described, and are not involved in the intensive folding and overthrusting that has affected the Georgian, Normanskill and Snake Hill beds, although they may dip steeply near the fault planes. Owing to their uniform softness and flat position, they have not only been very deeply eroded but also fail to form ridges of folded harder beds, as the other shale formations of the region do. Outcrops are therefore extremely scarce in the entire belt, occurring only where the creeks have accidentally reached a higher part of the shale surface, that for the most part is deeply buried under drift. Since practically every outcrop of this shale is fossiliferous, most outcrops are marked on the map as fossil localities.

On the Saratoga quadrangle the most important outcrops are about Ballston Spa where the Kayaderosseras flows between cliffs of this shale 100 feet high. A few small outcrops sufficient to demonstrate the areal extent of the formation were observed in the bed of the Glowegee and its branches, in the southwest corner of the Saratoga map, and another in the creek bed at the Geyser and Carlsbad springs 2 miles southwest of Saratoga Springs. Thence northeastward all rock is hopelessly buried under sand until the Snook kill is reached, which in its upper branches exposes shale cliffs at the foot of Mt McGregor and falls and flows over Canajoharie rock for several miles north of Gansevoort. It again reaches bedrock about 4 miles above the mouth of the creek.

The *thickness* of this formation could not be determined in the area here mapped from the facts at hand. We know, however, that not more than 15 miles to the southwest it is not less than 1100 feet and there is no reason why it should originally have greatly diminished toward Saratoga county, this direction lying in line with the probable axis of the trough in which deposition took place. Since, however, the shale in this region was earlier uncovered by erosion than the belt at the foot of the Helderberg escarpment, it probably has suffered a longer erosion and may for that reason be now much reduced in thickness.

The fauna of these shales on the two quadrangles is small but present in all outcrops and characteristic of the formation. It consists of the graptolites:

Corynoides calicularis *Nicholson*
Dicranograptus nicholsoni *Hopkinson*
Diplograptus amplexicaulis *Hall*
D. (Mesograptus) putillus *Hall*
D. (Mesograptus) mohawkensis *Rued.*
Climacograptus spiniferus *Rued.*
Glossograptus quadrimucronatus *mut.* cornutus *Rued.* and other mutations
Lasiograptus eucharis (*Hall*)

Besides these there are met with worms (Eopolychaetus albaniensis and Pontobdellopsis cometa) described from this formation by the writer in Bulletin 42 (1901) and small brachiopods (Leptobolus insignis Hall, Schizocrania filosa Hall) and a few cephalopods (Trocholites ammonius Conrad, Orthoceras arcuolineatum Rued., O. hudsonicum Rued.) and rarely a head of a Triarthrus becki. Of these are common only Corynoides calicularis, Climacograptus spiniferus, Diplograptus amplexicaulis, putillus, mohawkensis and Lasiograptus eucharis. Dicranograptus nicholsoni, so common in the Snake Hill beds, is very rare, while Lasiograptus eucharis is present in every outcrop; the other graptolites here cited are not always associated but rather distributed in subzones of the formation not yet distinguished. Thus in Ballston Spa the beds exposed in the village are full of Climacograptus spiniferus and Diplograptus amplexicaulis, but going up the Kayaderosseras creek one first meets thick-bedded mud shales and above these Glossograptus quadrimucronatus mut. and Lasiograptus eucharis have become the dominant forms. The outcrop at the Carlsbad Spring near Saratoga contains:

Diplograptus (Mesograptus) mohawkensis
Climacograptus spiniferus, and
Lasiograptus eucharis

As a rule, one meets only Corynoides calicularis and Lasiograptus eucharis, the two most common fossils, as at the Glowegee and the upper branches of the Snook kill. At the Gansevoort fall, however, also Glossograptus quadrimucronatus mut. cornutus, a characteristic form of an upper horizon of the Canajoharie shale was obtained in typical specimens.

Correlation. We have shown in another paper,[1] that the Canajoharie is of lower Trenton age and essentially contemporaneous with the Snake Hill shale. The two have, therefore, some important horizon markers, especially graptolites, in common. While, however, the Snake Hill shale rests on either upper Normanskill shale or Rysedorph Hill conglomerate and belongs to a vertical series that begins with the Georgian beds at the bottom, the Canajoharie shale can be seen to rest on the basal Trenton limestone at Glens Falls, the latter being underlain in turn by the Amsterdam limestone. It is therefore to be inferred that although the Canajoharie and Snake Hill shales may be approximately synchronous, they were formed in different basins and have come in contact through later diastrophic movements (see diagram and page 100.)

The Canajoharie shale is equivalent to the lower part of the Martinsburg shale in Pennsylvania and New Jersey, with which it has the characteristic fossils in common and is probably continuous with it through southern New York. The Martinsburg shale, however, comprises also beds of Utica and Eden age.

THE SCHENECTADY FORMATION

In the southwestern corner of the Saratoga sheet, from Birchton westward, the grits of the Schenectady formation are exposed in a number of places, showing that this formation just reaches the sheet from the southwest.

The Schenectady formation consists in the lower Mohawk valley of 2000 feet of grits and sandstones with interbedded black and gray argillaceous shales, the two forming a monotonous, uniformly alternating series throughout this great thickness. The sandstone beds are quarried about Schenectady and Aqueduct, and in the latter place, where the Mohawk river in its new postglacial course breaks through a ridge of these harder beds, an excellent section of a portion of the formation is furnished. These gray, impure sandstones and gray to black argillaceous shales have, until recently,

[1] N. Y. State Mus. Bul. 162, p. 29.

been currently correlated with the " Hudson River," Lorraine or Frankfort formations, mainly for the reason that they overlie the black (Canajoharie) shales, which were identified with the Utica shale; further because they are lithologically like the Lorraine beds; and, finally, because they seem to be continuous westward with the Frankfort shale, the lower division of the Lorraine group as it was hitherto understood. Recent investigations by the writer[1] have, however, shown that this thick formation contains a fauna not younger than Trenton, that the underlying black shale is not Utica but early Trenton in age, and that these sandstones and shales are only apparently continuous with the Frankfort of the Mohawk, the Frankfort pinching out gradually eastward and the Schenectady beds rapidly thinning out westward. The Schenectady formation is therefore now considered as of middle and upper Trenton age.

The life of this formation has proved to be an extremely peculiar one. It consists of a few graptolites, brachiopods, cephalopods, lamellibranchs, trilobites and ostracods of upper Trenton aspect, with prenuncial Utica forms, but besides there occurs, in certain layers, a profuse mass of fragments of new eurypterids and seaweeds (*Sphenophycus latifolius*). Ten species of eurypterids, belonging to various genera, have so far been recognized, but it is obvious from fragments of sculptured pieces of integument that the fauna was still greater. The seaweeds, the rapid alternations of shales and sandstones and the mud cracks indicate that the great thickness of beds was deposited in shallow water, and the uniformity of the formation shows that this water kept deepening approximately proportional to the accumulation of the sediments. The formation extends mainly from southwest to northeast in a trough that is here termed the lower Mohawk or western trough.

While at present the formation reaches only the southwestern corner of the Saratoga quadrangle, its great thickness on the adjoining Schenectady quadrangle, and the fact that the strike of the formation is in the direction of this sheet, leave no doubt that it once extended much farther north, probably across the sheet, and has since been eroded away.

The edge of the formation forms now a low escarpment, shown by the contour lines in the very southwest corner of the sheet, and this, like the typical Helderberg escarpment, farther south, is clear evidence of the former extension farther northward of the formation.

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[1] *Op. cit.*, p. 50.

In front of this low escarpment, at several places along the road leading due north to the Glowegee, small outcrops of dark shales were observed, the shale being sandy in some parts and fissile and argillaceous in others, but nowhere of the character of the Canajoharie shale. This shale we have mapped with the Schenectady beds.[1]

The Indian Ladder beds. The Schenectady beds are overlain in the Helderberg escarpment at the Indian Ladder by a similar formation, 300 feet or more in thickness, that has furnished a faunule hitherto known only from the Eden beds about Cincinnati and of an age roughly corresponding to that of the Frankfort beds in central New York. This formation, which is of small east-west extension, was deposited after an emergence in Utica time in the narrow southern extension of the western trough. The submersion, however, proceeded probably from the south, and it is very probable that it extended over the Saratoga sheet, although no rocks of this period are left there.

STRUCTURAL GEOLOGY OF THE WESTERN BASIN

BY H. P. CUSHING

General statement. The Paleozoic rocks of the western basin have been deformed chiefly by faulting, which has equally affected the Precambric rocks. Folds are not prominent and the rocks show but gentle dips, except locally near faults. The district shows little sign of lateral compression and the faults all appear to be normal. In these two respects arises the chief structural difference between the rocks of the western and eastern basins.

Vanuxem, years ago, described the normal faults which cross the Mohawk valley, from Little Falls to Hoffmans Ferry.[2] The next geologist to consider them in any detail was Darton, who studied and mapped all the Mohawk faults, especially extending the work north of the river, and also carrying it northeastward to include the Saratoga region.[3] This was a most excellent piece of work and has formed the basis for all subsequent investigation of these faults.

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[1] Professor Miller has, on the adjoining (Broadalbin) quadrangle, mapped the sandstone-shale alternations of the Schenectady formation as Frankfort beds, and the underlying shale of the same formation, as Utica, the Schenectady beds having at that time not yet been studied by the writer and separated from the Frankfort shale.

[2] Geology, 3d Dist., p. 203–11.

[3] N. Y. State Geol. 14th Ann. Rep't, 1894, p. 33–53.

Still more recent work on some of the faults which reach the Saratoga quadrangle has been done by Prosser, Cumings and Fisher in their mapping of the Hoffmans Ferry fault across the Amsterdam quadrangle, near the north edge of which it gives rise to two branches; and by Miller in his mapping of these and other faults of the Broadalbin quadrangle.[1] Of these only the Hoffmans Ferry fault and branches pass over on the Saratoga quadrangle, while other and more easterly faults come in.

All the larger of these Mohawk faults have a trend somewhat to the east of north, and a rude parallelism with one another. To the south they all run into the great thickness of upper Ordovicic shales, and as soon as these come to form the surface rocks on both sides of the fault, it is exceedingly difficult to trace the dislocation farther. We do not as yet know whether they die out in the shales or not. To the north the faults run into the Precambric rocks; and so soon as they have these on both sides of the fault, a similar difficulty arises in the effort to trace them farther. But they seem to run entirely across the Adirondack region from south to north and diminish in frequency toward the west. Hence it results that they abound in the southeast border of the region and are practically absent on the northwest. With their parallelism they divide the region into a great series of rock slices or segments which have shifted up and down past one another and broken the continuity of the rock formations.

The fault planes are seldom visible but such evidence as we have indicates that they are nearly vertical breaks and are all of the type known as normal faults. In the great majority of them the east side has dropped in level relatively to the west side, but in a few of them the reverse is true.

In addition to the relative displacements of the adjacent slices along the fault planes, the upper surfaces of the slices have usually received a tilt toward the west, each slice thus constituting the upthrow side of a fault along its east edge, and the downthrow side of the next fault along its west edge, as illustrated in figure 4.

The faults. Two of the great faults of the Mohawk region, the Hoffmans Ferry (much better abbreviated to Hoffmans) and the McGregor fault, the latter here named for the first time, cross the Saratoga quadrangle. The remaining faults mapped are branches of these two great breaks.

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[1] N. Y. State Mus. Bul. 34 and map; Bul. 153 and map.

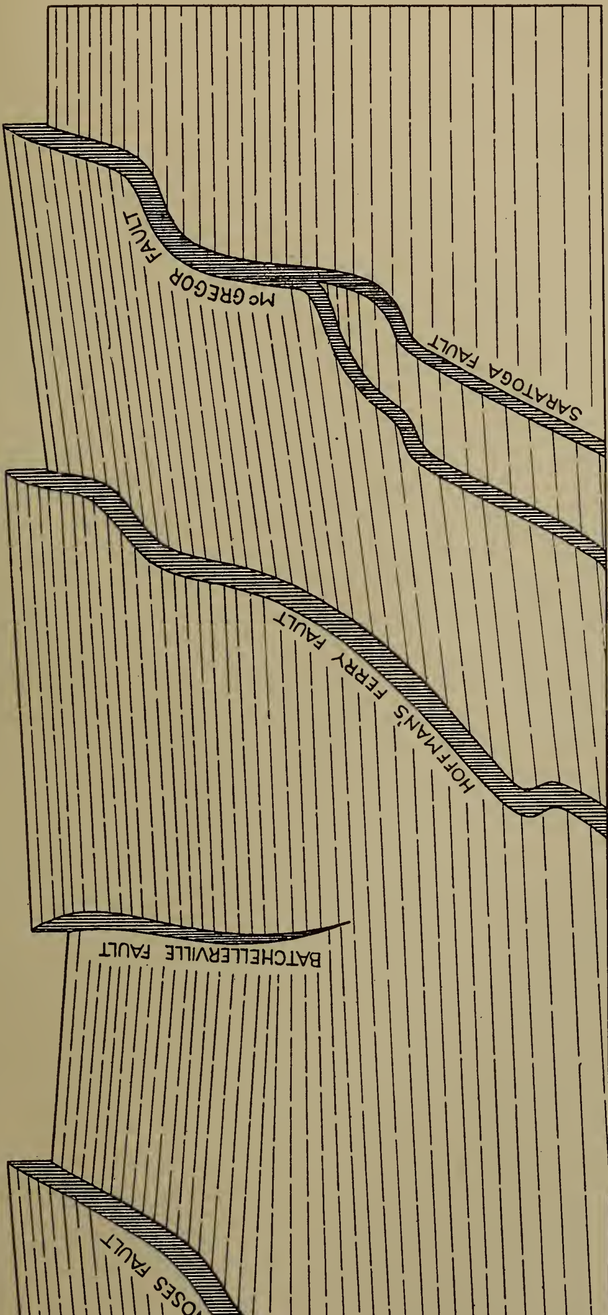

Fig. 4 Diagram of the four principal faults of the Saratoga and Broadalbin quadrangles to illustrate the manner in which they longitudinally slice the country. Minor faults and branch faults are omitted. The Batchellerville fault also is not a member of the principal group but a subsidiary break in the block between the Noses and Hoffmans Ferry faults. Vertical scale greatly exaggerated.

The Hoffmans fault enters the Saratoga quadrangle on its west margin 1 mile northwest of East Galway and, pursuing a general north-northeast course passes on to the Luzerne sheet a mile west of Corinth. At Hoffmans Ferry on the Mohawk (Amsterdam quadrangle) the displacement is estimated by Cumings at 1300 feet and by Prosser at 1600 feet.[1] Near the north edge of the Amsterdam quadrangle the fault sends off two branches to the east, each of which takes part of the throw of the main fault. These two branches, called by Miller the West Galway and East Galway faults, continue across the Broadalbin quadrangle on to Saratoga. Across Broadalbin, Miller estimates the throw of the Hoffman fault as but 250 feet, but states that this rapidly increases in its course across the Saratoga quadrangle.[2]

The scarp of the Hoffmans fault is the most prominent topographic feature of the Saratoga region, though nearly equalled by the McGregor scarp. The summit knobs of the range reach elevations of over 2000 feet, towering as the west wall of the Kayaderosseras valley, the valley floor not greatly exceeding 600 feet altitude. None but Precambric rocks occur west of the fault within the quadrangle; but east of it such heavy drift is banked up against the face of the fault scarp all the way from East Galway to near South Corinth that no rock exposures are seen. About South Corinth Precambric rocks are at the surface east of the fault; about East Galway rocks of the Theresa formation are at the surface. What lies between the two is chiefly conjectural. But the rapid increase in prominence of the fault scarp in passing north from East Galway can, in this instance, be due to nothing except increasing throw. The surface of the western block is tipped to the south more than that of the eastern block. Back from Corinth therefore the throw is equal to the height of the fault scarp plus an unknown amount; hence Miller's estimate of 1000 feet is modest, and the throw is likely 500 feet in excess of that.

To recapitulate: the great throw of the Hoffmans fault at Hoffmans Ferry is split into three parts by the branching of the fault so that, across the Broadalbin quadrangle, the main fault retains only

[1] In vertical faults in nearly horizontal rocks, such as these, the displacement is practically all throw, so far as can be told. At Hoffmans Ferry the surface beds on the western, or upthrow, side of the fault are buried under a thickness of from 1300 to 1600 feet of younger rocks on the opposite side, according to these estimates. Relatively to the beds on the western side the corresponding ones on the east have been vertically dropped by that amount.

[2] N. Y. State Mus. Bul. 153, p. 46.

a small fraction of its original throw, the remainder being taken up apparently by the branch faults (West and East Galway faults). Across the Saratoga quadrangle the main fault rapidly regains its original amount of throw. This would naturally suggest a loss of throw in the case of the two branch faults, and such meager evidence as we have in regard to them is corroborative of this suggestion.

West Galway fault. The West and East Galway faults enter the Saratoga quadrangle near its southwestern corner and not greatly over half a mile apart. They are easily traced for 3 or 4 miles when they run into heavily drift-covered territory in which their course, and even their existence, is quite uncertain. Where outcrops reappear, in the northern portion of the quadrangle, two faults are found which are on the trend of these two, and they are assumed to be their prolongations; but the uncertainty of this must be emphasized. If the assumption is correct, interesting consequences follow.

South of East Galway the ravine that runs across the West Galway fault, and which cuts down into the Precambric just west of the fault line (see areal map), gives the data for an approximate estimate of the fault's throw at that point. The Precambric is on one side, the upper portion of the Theresa formation on the other, so that the throw is just about equivalent to the combined thicknesses of the Potsdam and Theresa formations, or from 250 to 300 feet.

Near this point, one and one-half miles south of East Galway, there is a dropped wedge of rock, or horse, along the West Galway fault, which is interesting because the rock concerned is much younger than on either side of the fault. Potsdam sandstone adjoins it on the west or upthrow side of the fault, and the upper beds of the Theresa formation on the other side, the downthrow. The rock of the included wedge is upper Little Falls and basal Amsterdam, hence higher in the section than the Theresa on the downthrow side by the full thickness of the Little Falls dolomite, at least 300 feet. Figure 5 shows a plan of the outcrops and our interpretation of the relations. The wedge of Little Falls and Amsterdam shows abundant outcrops. At the north end of the wedge and *apparently* on the

FIG. 5 Plan of outcrops on the West Galway fault, showing the wedge with Little Falls dolomite at the north and Amsterdam limestone at the south, with two additional outcrops, no. 1 of Theresa beds and no. 2 of Potsdam sandstone.
Scale 1 inch=350 yards.

east side of the fault, at a slightly lower level than the nearby Little Falls, is an outcrop of the Theresa passage beds; at the south end, and unquestionably on the west side of the fault, Potsdam sandstone outcrops. Farther west outcrops are plentiful on the west side of the fault but there are none on the east side. The uncertainty in regard to the matter is whether the Theresa is really on the east side of the fault; a slight swinging of the northern apex of the wedge toward the right would put it on the west side. The uncertainty is regrettable; we can only say that everything we saw in the field led to the confident belief in the relations as illustrated, and had not the Theresa exposure been forthcoming we should have been forced to map it at that point owing to the testimony of exposures a mile to the southwest. Nevertheless the drift is very heavy and the mapping of a much faulted district such as this must needs be very uncertain under the circumstances.

Rock horses caught in along faults are common enough. But the rock concerned is usually intermediate in age between the rock of the upthrow and downthrow sides; it has dropped relatively to the upthrow side but has not dropped so far as has the downthrow side. Such a wedge occurs in Saratoga along the Saratoga fault. But in the case under consideration we have a small block about 350 yards in length, which has dropped down along the fault zone some 300 feet more than the downthrow side has dropped. It is a diminutive example of a trough fault. It is difficult to conceive of the mechanical conditions which would permit so small a block to drop so deeply into the jaws of a fault. It may be the apex of a large dropped block, otherwise entirely eroded away.

What seems to be another and similar case is found along the Hoffmans fault a mile west of Porter Corners where a small block of Little Falls dolomite lies in the fault zone closely adjacent to the Precambric exposures to the west of the fault. To the east the drift covers everything, but unless our attempted mapping is totally at fault, the rock on the downthrow side should be the Potsdam sandstone. Certainly Precambric rocks come in on the east side of the fault 2 miles away to the northeast. So we infer this to be a small dropped block of the same type.

As has been said, the mapping of the West Galway fault across the quadrangle is highly conjectural. There should be a fault between the Precambric exposures south of South Corinth and those of the Theresa at North Greenfield; there should be a fault just west of the Potsdam exposures at Corinth, cutting them off.

Plate 11

Rock City falls over Calciferous sandstone; student standing on its top with Trenton above.

These are on the same line with one another and also about on line with the prolongation of the West Galway fault. The throw also is much the same so far as can be judged, but the direct evidence is meager.

East Galway fault. The evidence for the extension of this fault as far as Middlegrove is fairly satisfactory. At first it shows Canajoharie shales on the downthrow side. Back from Rock City Falls the Amsterdam and the Little Falls come in. On the upthrow side the horizon varies but little, the surface of the slice lying very flat. Beyond Middlegrove it runs into the heavy drift, but its trend would be with the axis of the preglacial valley for the next few miles. Farther north its occurrence is problematical, but the presence of a fault is needed to explain the occurrence of the Potsdam and Theresa formations at and south of Corinth, which are wholly out of adjustment with the same formations in the eastern part of Greenfield township. We think a fault must lie here, and it seems more reasonable to connect it with the East Galway fault than to assume a wholly separate break. The chief objection to this view is that the fault south of Corinth downthrows to the west, while at East Galway the downthrow is to the east. This may be explained, however, by the fact that the slice of territory to the west of the fault lies very flat, while to the east of the fault the rocks are more tipped, having a very noticeable southwest dip. Because of this the throw steadily diminishes in passing north as far as a point southeast of Porter Corners, where the Theresa formation is present on both sides of the fault and the throw has become zero. To the northward the throw reverses and the older rocks are present on the east side of the fault instead of on the west. Faults of this type, called "rotatory" faults, are not very common, which is the cause for greater regret, as the heavy drift-covering makes the whole matter so uncertain.

Rock City Falls fault. The small fault at Rock City Falls has been described by both Darton and Prosser. It is well exposed in the creek, the fall itself being practically on the fault line, 15 feet of Little Falls dolomite underlying the Amsterdam on the west or upthrow side, while the base of the Amsterdam is below the creek level on the downthrow side. To the south of the creek also recent quarrying of the Amsterdam has exposed the fault line excellently for a short distance, though with Amsterdam limestone on both sides, a little fault breccia, and with much updrag of the rock on the downthrow side. The throw of the fault is only 25 to 30 feet.

Southward it runs into shales and can not be traced. Northward there are indications of it for a mile, beyond which it is hidden by drift.

McGregor fault. Darton spoke of the group of faults about Saratoga as the Saratoga faults. The group seems to us to consist of a main fault with branches and we desire to retain the name Saratoga fault for the branch in the village, often called the "Springs" fault. The grand scarp of the main fault along the front of Mt McGregor has suggested that as a most fitting name for this fault.

In front of Mt McGregor the fault has Precambric rocks on the upthrow side and Canajoharie shale on the downthrow, so that the full thickness of the Potsdam, Theresa, Hoyt, Little Falls and Amsterdam formations is faulted out. This means a minimum thickness of at least 600 feet; in addition there is another thickness of 600 feet of Precambric in the fault scarp, with the summit likely 200 feet below the horizon of the base of the Potsdam. How much thickness of the Canajoharie shale is involved is uncertain, but the throw of the fault is certainly 1400 feet at Mt McGregor, and likely 200 feet more than that. It seems to be increasing toward the north.

Near Kings Station, 4 miles north of Saratoga, a branch fault sets off from the main fault toward the northeast, bringing a block of Little Falls dolomite to the surface between the shales and the Precambric. This may be called the Gurnspring fault. Carbonated waters rise along it in the same way and under very similar structural conditions as they do along the Saratoga fault. This block of dolomite seems cut off at the north by shales, and hence by another fault, but rock outcrops are so few that conditions are very conjectural.

To the northward the McGregor fault runs as one of the prominent breaks of the region, passing to Lake George and forming the prominent fault scarp along the west shore of the lake and of Northwest bay, at the apex of which it passes inland away from the lake.

Between Kings Station and St Clements the McGregor fault runs unbroken, but at the latter place, somewhat over a mile north of Saratoga, it sends off two branches, much diminishing the throw of the main fault. This swerves around to the west and becomes eventually lost under the heavy drift of the Kayaderosseras valley. Its throw is rapidly diminishing and it probably dies out in that district.

Woodlawn Park fault. The first of the two branches given off from the main fault at St Clements may be named from this park, as it runs through its northern portion. The only rock outcrop in this portion of the fault block is the Hoyt limestone exposure at the railroad quarry, closely adjacent to Precambric on the north and to Little Falls dolomite on the west and south. Farther south abundant exposures of Little Falls dolomite and overlying Amsterdam limestone occur within the fault block, while across the fault to the southeast is drift-covered territory with Canajoharie shale for the surface rock. Then the fault runs into shales and is lost, as happens to all the faults of the region in like circumstance. The throw of this fault north of Saratoga is just about the thickness of the Little Falls dolomite in amount, hence 300 feet at least.

Saratoga fault. The second branch given off from the main fault at St Clements follows the strike of the main fault into Saratoga and the upthrow side is constituted of the platform of Little Falls dolomite on which the western half of the village is built. At the north edge of the village the strike of the fault swerves somewhat to the west and so continues to West Congress street and Broadway, where it swerves sharply to the west. This part of its course is covered by drift but the change in direction has been disclosed by excavations made for sewers, the data having been furnished by Mr S. J. Mott, the village engineer. By these means the fault has been traced in this direction for something like one-third of a mile, after which its course is largely conjectural.

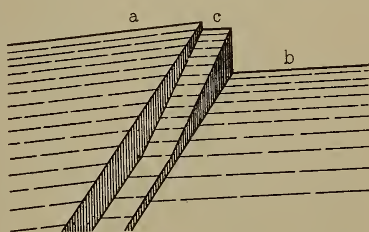

Fig. 6 Diagram of the Saratoga fault and the tipped wedge of Amsterdam limestone in the northern part of Saratoga Springs; a = upthrow side of Little Falls dolomite; b = downthrow side of Canajoharie shale; c = Amsterdam wedge; vertical scale and tilt of wedge surface exaggerated

The fault has long been known because of its close association with the older springs at Saratoga, but when compared with the other breaks of the region its notoriety is found to be out of all proportion to its magnitude. It is but a small break. In its course through the village there is everywhere associated with it a narrow wedge of Amsterdam limestone caught in along the fault zone. This is best seen back of the Star spring and thence northward for a few rods. The low fault scarp, 20 to 25 feet in height, shows the upper beds of the Little Falls dolomite, and is today best shown back of the High Rock spring (plate 8). Small patches of basal Amsterdam lying in contact with the Little Falls somewhat farther north show that this is the very summit of the formation. At the Star spring a wedge of Amsterdam limestone appears lying closely against the fault face and with a tipped upper surface, rising toward the north, falling toward the south. Back of the Red spring it has risen to the full height of the fault scarp; at the High Rock spring it is some 15 feet below the surface of the ground. Figures 6 and 7 clearly show the disposition of this wedge of Amsterdam.

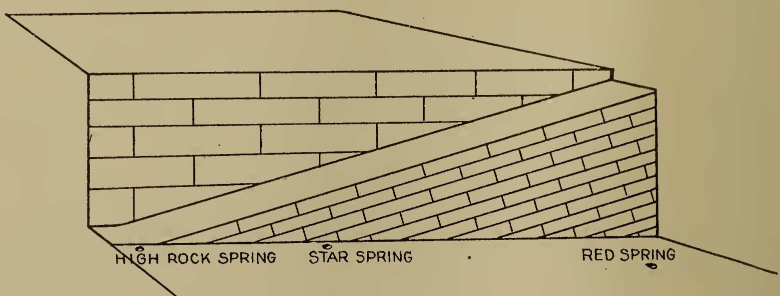

Fig. 7 Illustration of the manner in which the tipped block of Amsterdam limestone lies against the fault face, as seen in looking at the fault from the downthrow side; tilt of block much exaggerated; 1 = Red spring, 2 = Star spring, 3 = High Rock spring.

At the Star spring a drilled well gave 38 feet of drift and 62 feet of shale before reaching the summit of the Amsterdam limestone. This well is only a very few yards east of the Amsterdam wedge outcrop and the fault line, showing clearly that the wedge is but a very narrow block caught in along the fault. Ignoring it and estimating the throw of the Saratoga fault from the exposures and the well record at the Star spring, a result of about 160 feet is obtained, 100 feet of drift and shale, 40 feet of Amsterdam limestone and the 20 feet of Little Falls shown in the fault scarp.

The Amsterdam wedge seems to continue along the fault all the way through Saratoga between the two swerves in its course. This is indicated by the fact that it is the surface rock just east of the fault at the Hathorn spring, and also is the surface rock at the Congress spring, as shown by the drill core. It really amounts to a parallel fault lying very close to the main fault. South of the Congress spring its course is lost under heavy drift.

Hathorn spring record. The deep bore at the Hathorn spring went down 1006 feet. The driller reported 62 feet of drift at the top and 231 feet of Potsdam sandstone at the bottom, the drill resting in this formation. Amsterdam limestone was found directly under the drift. The Potsdam is so thick that it seems that the full thickness of the Theresa must also be included. If this be the case, the Hoyt, Little Falls, and Amsterdam have a combined thickness of 713 feet, whereas judging by such other evidence as we have of their thickness it should not exceed 450 to 500 feet. This suggests that the drill may have crossed a fault so as to go through a certain thickness of beds twice. This would be quite possible since the drilling started on the Amsterdam wedge and it is only necessary to assume that the branch of the fault east of the wedge hades toward the main fault in order to have just the necessary conditions, as illustrated in figure 8. The drill core is in existence but we have not had opportunity to study it. Such study should show whether any part of the section is duplicated in the record or not. If there is duplication the illustration probably furnishes the reason. If there is none, then the Little Falls dolomite and Hoyt limestone taken together are considerably thicker than we have supposed.

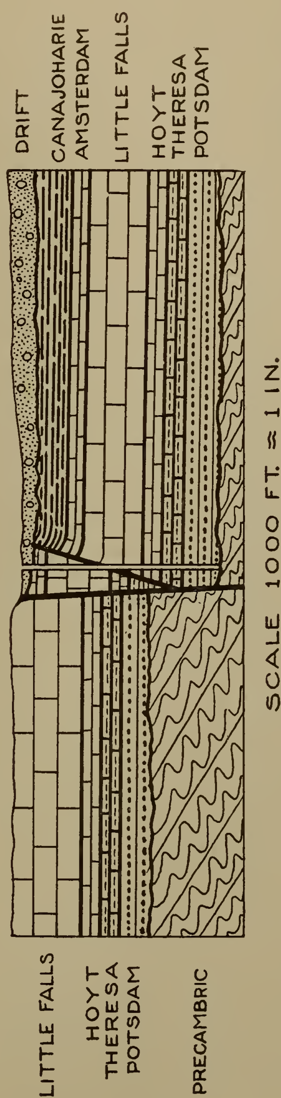

Fig. 8 Diagram to illustrate supposed underground conditions at the Hathorn spring, in explanation of the great thickness of Paleozoic rock shown in the well. Starting in the Amsterdam wedge the bore is thought to pass across the branch fault and repeat part of the section already passed through.

General remarks on the faults. The large faults of the Mohawk and eastern Adirondack regions show a frequent tendency to curve from the north to the northeast and from the northeast back to the north. It has been shown that there are principal joint sets in both these directions in the region and the fault slips are thought to be determined in position by these joints. The average trend of the faults is to the north-northeast. In this direction there are no main joints. The faults maintain this general direction by alternately following the north and the northeast joints, this apparently being a more easy method of accomplishing the deformation with north-northeast trend than the method of creating new fractures in that direction along which the slipping might take place. Both the Hoffmans and the McGregor faults illustrate this curving tendency.

The faults send off frequent branches, which are more likely to appear at a curve. In many cases one branch will be found in a north-south and the other in a northeast-southwest direction. By the branching, the throw of the fault is divided among the branches. It often happens that the throw of the branches steadily diminishes until they fade out while at the same time that of the main fault increases until it attains the amount it had prior to the branching. This process seems frequently repeated.

During the successive stages of the faulting in the region, as the long rock slices slipped past one another, it is but natural that irregularities in the slipping would develop, producing cross strains in the slices and tending to promote cross breaks. That such cross breaks are of frequent occurrence in the general region is quite certain, though exposures are not sufficiently good to permit their certain location within the Saratoga quadrangle. The obvious tendency would be for such cross breaks to occur along planes of weakness, such as the contacts between two formations of very different strength. There seem to be two zones in which such breaks would be most apt to occur, one at the contact between the Precambric crystallines and the Potsdam sandstone, and the other at the contact between the limestones and the overlying shales.

There is some suggestion of frequent cross breaks in the faulted slices at the Precambric-Potsdam contacts, but in no case known to us has the evidence been worked out in detail. A prominent topographic feature of the southeast border of the Adirondacks is the way in which the Precambric portions of the fault slices sharply break down on the south to the level of the Paleozoic plain. In every one of the faulted slices the Precambric rocks are followed by Paleozoic rocks on the south. The Precambric territory is commonly elevated territory, the Paleozoic contrastingly at low altitude. The abrupt way in which such Precambric ridges as those of French and Putnam mountains, and of Sugar Loaf, on the Glens Falls quadrangle, break off at the south, with an abrupt drop in level of from 500 to 800 feet, would seem of necessity to imply cross faulting in the fault slices concerned.

On the Saratoga quadrangle the evidence for cross breaks at the contact between the Amsterdam limestone and the overlying Canajoharie shale seems quite conclusive. The Amsterdam dips to the south are always higher than those of the Little Falls dolomite, showing downfolding or downdragging in that direction, and in the shales the dips are even higher for a time, so that even close to the Amsterdam border the thickness of shale over the limestone is considerable. Exposures do not suffice to determine whether we are dealing with monoclinal folding or with faulting; but since the former could be considered merely an initial phase of the latter, either one would indicate the horizon as a likely one for cross breaks.

Joints. Our readings on joint directions on the Saratoga quadrangle are not sufficiently numerous to make it worth while to plot them. The Precambric rocks cover but a small portion of the quadrangle. They are as usual much jointed nearly everywhere and appear to be referable to four sets, a north-south, an east-west, a northeast and a northwest set. But they do not hold their direction true, curving through considerable arcs. In the Grenville strike joints are prominent, in this case the east-west set. Of the vertical joints the northeast set is the most prominent, the north and the northwest less so and more irregular. The Paleozoic rocks are not very sharply jointed in the main, and the joint directions are very irregular.

PALEOZOIC ROCKS OF THE EASTERN TROUGH

BY R. RUEDEMANN

All the sedimentary formations of the eastern trough in the Saratoga and Schuylerville quadrangles belong to the Cambric and Ordovicic (Lower Siluric) systems. The following stratigraphic units have been distinguished:

Table of formations exposed

Ordovicic	Trenton	9 Snake Hill shale
		8 Upper Normanskill shale with Rysedorph Hill conglomerate
	Chazy	7 Normanskill shale *s. str.*
	Beekmantown	6 Bald Mountain limestone
		5 Deep Kill shale (possibly present)
		4 Schaghticoke shale
Cambric	Georgian or Taconic	3 Schodack shales and limestones
		2 Eddy Hill grit
		1 Bomoseen grit

The Cambric system is represented only by its lowest group, the Georgian. The Georgian rocks are found only along the eastern edge of the Schuylerville sheet, whence they extend eastward over the Greenwich and Rensselaer plateaus. The discovery and demonstration of the presence of Lower Cambric rocks, now known as Georgian, may be said to have taken place right at this eastern edge, for it was from the neighborhood of Bald mountain that Dr Ebenezer Emmons obtained the fossils Elliptocephalus asaphoides and Atops trilineatus which demonstrated, in that well-known controversy on the Cambric system in America (Emmons's Taconic), the presence of rocks as old as the Primordial stage of Barrande in the slate belt of eastern New York. Through the investigations of Ford, and especially those of Walcott and Dale, the faunas and rock types of the Georgian have become well known. Walcott[1] first clearly separated the Georgian and Ordovician terranes, and Dale[2]

[1] The Taconic System of Emmons. Amer. Jour. Science, 1888, 35:229, 307.

[2] Dale, T. Nelson. New York-Vermont Slate Belt. U. S. Geol. Surv. 19th Ann. Rep't, 1893, p. 153.

established the succession of the subdivisions of the Georgian with such accuracy as the great difficulties arising from the extremely disturbed condition of the beds will permit. He distinguishes, in ascending order (see chart facing page 178, *op. cit.*):

A *Olive grit.* Olive green grit (graywacke), more or less massive, spangled with minute scales of hematite or graphite, sometimes with small quartzite beds, frequently calcareous, generally weathering a pale brick red. Associated with it in places a bed of quartzite 12 to 55 feet thick, 50 to 200 feet.

B *Cambric roofing slates.* Roofing slate, grayish green, purple or mixed green and purple, alternating with beds of calcareous quartzite up to 5 feet and limestone breccia up to 40 feet thick. Fauna: Olenellus; Microdiscus lobatus, M. speciosus; M. connexus; Solenopleura, possibly nana; Obolella; Iphidea pannula; Hyolithes communis; Hyolithellus micans; trails of annelids. 200 to 240 feet.

C *Black patch grit.* Dark gray grit or sandstone with black shaly patches, sometimes with calcareous nodules. Olenellus in both grit and calcareous nodules. 10 to 40 feet.

D *Cambric black shale.* Black shale or slate, generally weathering blue black, sometimes pyritiferous, with thin beds of limestone and less frequently limestone breccia. Fauna: Linnarsonia sagittalis var. taconica; Orthis, probably salemensis; Lingula?; Lingulella coelata?; Lingulella granvillensis; Hyolithes communis; Leperditia dermatoidea; Conocoryphe — sp.?; Solenopleura, probably tumida; a phyllocarid crustacean, closely related to Ceratiocaris; spicules of Protospongia; also Microdiscus speciosus; M. lobatus and Iphidea pannula. 50 to 250 feet.

E *Ferruginous quartzite and sandstone.* Quartzite, usually with spots of limonite; in places, however, a bluish calcareous sandstone (grains of quartz with a calcareous and ferruginous cement). 25 to 100 feet.

Professor Dale found 335 to 1400 feet of Lower Cambric rocks exposed but since the thickness of the basal member, the olive grit, is not known, the thickness may easily exceed the maximum. The upper divisions, C, D and E, are described as intermittent and B as often wanting in the western part.

In a later paper Dale[1] has arranged the Georgian beds of the region adjoining south of the one here discussed, somewhat differently. He there constructs the following table of formations:

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[1] Dale, T. Nelson. Geology of the Hudson Valley between the Hoosic and the Kinderhook. U. S. Geol. Surv. Bul. 242, 1904, p. 29.

Table showing the Lower Cambric series as exposed in Rensselaer county and part of Columbia county, N. Y.

SERIAL LETTER	DESCRIPTION OF STRATA	FAUNA	ESTIMATED THICKNESS IN FEET
J	Greenish shale..................	....	50
I	Thin-bedded limestone, or dolomitic limestone, in varying alternations with black or greenish shale and calcareous quartz sandstone. Some of the limestone beds brecciated within the sandstone or shale and forming brecciation pebbles, in places, however, beach pebbles	Olenellus fauna......	[a] 20–200
H	Greenish, reddish, purplish shale, in places with small beds of more or less calcareous quartzite. At Troy, in upper part a 2½ foot bed of calcareous sandstone	Oldhamia, annelid trails Hyolithes and Hyolithellus	25?–100+
G	Granular quartzite, in places a calcareous sandstone	....	10–40
F	Olive grit, metamorphic, usually weathering reddish; absent at south	Traces of?..........	18–50
E	Greenish, or reddish and greenish, shale with small quartzite or grit beds	Casts of impressions, Oldhamia [b]	65–535
D	Massive greenish quartzite, in places very coarse	....	10–50
C	Reddish and greenish shale with small beds of quartzite or grit (rarely up to 5 feet thick)	Casts of impressions, Oldhamia	30–80
B	Massive greenish quartzite, in places very coarse	....	8–40
A	Reddish and greenish shale with small beds of quartzite or grit, from 1 to 12 and, rarely, 24 inches thick	Casts of impressions, Oldhamia	50–80

[a] Usually 50. [b] Oldhamia occurs in A, C, or E, and quite possibly in all three.

Minimum, 286. Maximum, 1225+

A comparison of the two series of divisions, that for the slate belt of Washington county and Vermont and that for Rensselaer county, furnished by Dale, shows that the olive grit in the first is overlain by a great mass of colored slate, the "Cambric roofing slates," and in the latter rests on a still greater mass of colored shales; further that the Cambric roofing slates and the Black patch grit are absent in the latter series, where a granular quartzite 10 to 40 feet thick and a second mass of colored shales 25? to 100+ feet thick intervene between the olive grit and the black shale and thin-bedded limestone. In Washington county this is followed by another quartz mass, the ferruginous quartzite, and in Rensselaer county by greenish shale.

In accordance with the present practice to name the units after their type localities instead of their lithologic and faunistic characteristics and to avoid confusion between the different horizons of colored shales and quartzites, we propose here the following names for these units:

1 *Bomoseen grit* (olive grit). Olive green grit, nearly a pale brick-red. Associated with it in places a bed of quartzite 12 to 55 feet thick. 50 to 200 feet. The type locality of this unit is, according to Dale, on the west side of Lake Bomoseen, Vt., "one-quarter of a mile west of the road running north from Hydeville, on the north side of road to Fairhaven." It is finely exposed about Greenwich, N. Y., especially in ridges northwest of that town, and south on Louse hill, but disappears in Rensselaer county where it still outcrops east and southeast of Troy.

2 *Mettawee slate* (Cambric roofing slate Dale). See definition, page 67. These slates extend typically from Pawlet, Vt., and Granville, N. Y., to Fairhaven, Vt. The town of Granville, which is the center of the industry, would furnish a good name if it were not preoccupied. We have therefore taken the name of the Mettawee river which drains the region.

3 *Eddy Hill grit* (Black patch grit). This formation, which is defined on page 67, is termed from Eddy Hill, near Fairhaven, Vt., where it is seen to rest on the Mettawee slate, and carries fragments of the Olenellus fauna. Its extension southward is not safely established on account of its great similarity to the "Hudson" grit.

4 *Schodack shales and limestones* (Cambric black shale). Defined on page 67. This formation of black shales and limestones always occurs near the top of the Georgian; it is well

exposed in many localities, as on Bald mountain near Greenwich, about Granville, etc. The name is taken from the fine exposures two miles south of Schodack Landing, N. Y., on the bank of the Hudson river and the belt of these rocks in the town of Schodack, N. Y.

5 *Nassau beds* (divisions A–E of Dale's series in Rensselaer county). In Rensselaer county the Olive grit or Bomoseen grit is underlain by a series of alternating reddish and greenish shales and quartzites containing Oldhamia, about 150 to 800 feet thick. This is especially well exposed in the town of Nassau, N. Y.

6 *Diamond Rock quartzite* (division G of Dale's Rensselaer series). This division 10 to 40 feet thick and composed of granular quartzite and associated calcareous sandstone, is well exposed in Oakwood cemetery and the "Diamond Rock" in Lansingburgh (North Troy), from which it takes its name.

7 *Troy shales* (division H of Dale's Rensselaer series). This formation, which follows upon the Diamond Rock quartzite, consists of 25 to 100 feet of colored shales with small beds of calcareous quartzite. The shale has furnished Oldhamia, a calcareous sandstone bed in the upper part Hyolithes and Hyolithellus. These beds are well exposed at Troy, at the dam in the Poesten kill and other localities.

8 *Zion Hill quartzite* (Ferruginous quartzite Dale). This name, taken from Zion hill, Hubbardtown, Vt., where according to Dale the ferruginous quartzite is exposed in a thickness of 70 feet, is proposed here for the sake of completeness.

On the Schuylerville sheet we find well represented only division A and the limestone and shales of D. We have separated the areas occupied by these two divisions on the map, the boundaries being only approximate on account of the interfolding of the beds.

The olive grit occupies the southern half of the area. It is easily recognized by the pale brick-red color of the weathered crust that forms on it; typically it is seen on the many ledges north of Greenwich, but it also appears on all sides of Louse hill and extends to the southern boundary of the Georgian areas. From Greenwich the grit skirts the eastern side of Bald mountain. It is described by Dale as follows:

A greenish, usually olive-colored, very rarely purplish, more or less massive grit, generally somewhat calcareous, and almost always spangled with very minute scales of hematite or graphite. Under the microscope it is seen to consist mainly of more or less angular grains of quartz, with a considerable number of plagioclase grains, rarely one of microcline, in a cement of sericite with some calcite and small areas of secondary quartz. There are large scales of muscovite and of a chloritic mineral, scarcely dichroic, and under polarized light a bluish green or prussian blue, with little or no change in rotation. More conspicuous and typical of the rock are scales from 0.043 to 0.130 by 0.020 millimeter, frequently bent, pale green, markedly dichroic, and under polarized light olive or slightly bluish green. These scales contain bands of a colorless mineral parallel to their cleavage, which measure 0.0043 in width and polarize in brilliant orange, emerald or blue. Extinction in both about (if not quite) parallel to cleavage and bands. Finally, there are grains or crystals of a muddy yellow under incident light, probably limonite and that after hematite. The scales of hematite, sometimes graphite, can be made out with a magnifying glass.

This characteristic rock can usually be identified at a distance by the peculiar pale brick-red color of its weathered surface, and, on closer inspection, by the minute spangles and the olive color of the fresh surface.

The olive grit has not furnished any fossils, but it was found full of carbonaceous blotches, suggesting seaweeds, and large worm trails. It is apparently a shallow water deposit.

The belts of heavier grit beds alternate with belts of more slaty, often brownish weathering beds, apparently resulting from the grit through a stronger development of the cleavage. These belts were found to be worn down more, forming the depressions between the ridges of harder grit.

The hills composed of this rock are frequently discerned from a distance through the reddish color of the soil they furnish. The Georgian limestones were also found to weather into soils of reddish tints so that as a whole the Georgian areas of this region can, to a large degree, be distinguished from the Ordovicic shale areas by the soils, wherever the drift is thin or its lower portion exposed, for, as a rule, this also contains so much material derived from the underlying rocks that it partakes of the reddish color. The olive grit forms a belt beginning at the projecting southeast corner of the Georgian area south of Louse hill, continuing over Louse hill and exposed on its north slope, on the banks of the Batten kill, continuing north of Greenwich to the central and eastern peaks of the Bald mountain ridge.

South and east of Louse hill the olive grit or the Bomoseen is flanked by massive ledges of gray quartzite speckled with brown spots of limonite. We consider this bed as corresponding to the massive beds of quartzite found farther east by Dale in association with the Bomoseen grit. On the centre peak of Bald mountain, the Bomoseen grit is flanked on both sides by quartzite beds which are followed by the shales and limestones of the Schodack beds, the whole probably forming an overturned abraded fold. This section would then indicate that the normal sequence is Bomoseen grit, Bomoseen quartzite, Schodack shales and limestone.

None of the typical roofing slates of the eastern part of the slate belt were observed in the Cambric area, but beds of calcareous quartzite, and especially brecciated limestones observed in connection with the Schodack beds, may represent this division.

The Schodack beds are especially well seen in the northern Georgian area of the sheet, where the black and gray shales and the interbedded limestones are everywhere exposed along the road skirting the base of the Georgian plateau in the town of Argyle. This area includes the well-known Bald mountain locality, where the black shales are seen with a thin quartzite bed directly above the quarry on the west side, while on the south side the olive grit has been drawn along the fault line into the shales. On the western slope of Bald mountain the thick-bedded, bluish limestones and interbedded dark gray to black partly arenaceous shale of the formation are well exposed.

Walcott, in his monumental monograph of the Cambric Brachiopoda (1912, page 197), records the following species from this neighborhood:

1 Limestones 1.5 miles (2.4 Km.) north of Bald mountain:

Obolus prindlei (*Walcott*)
Lingulella granvillensis *Walcott*
Obolella crassa (*Hall*)
Botsfordia caelata (*Hall*)
Acrotreta sagittalis taconica (*Walcott*)
Stenotheca rugosa (*Hall*)
Platyceras primaevum *Billings*
Hyolithellus micans *Billings*
H. micans rugosa *Walcott*
H. communis *Billings*
Elliptocephala asaphoides *Emmons*
Solenopleura tumida *Walcott*

2 Shaly limestone on the west slope of the summit of Bald mountain:

Botsfordia caelata (*Hall*)
Acrotreta emmonsi *Walcott*
Olenellus *sp.*

Professor Cushing and the writer collected a number of the species here recorded from the first locality and also on Bald mountain.

North of Bald mountain the thin-bedded, bluish (50+ feet thick) limestone is seen in sections to grade into more massive light gray limestone beds which, exposed in cliffs at the fault line, are liable to be confounded with the Bald Mountain limestone and may have led to the extension of the "Trenton" limestone belt farther northward than shown on our map. Georgian brachiopods were found in this massive limestone bed in at least two localities. These limestones were seen in several places to rest on black Cambric shales. It is therefore probable that the Schodack beds contain here some thicker limestone beds than observed in the more eastern region.

The area southeast of Louse hill consists of black shale, a thin-bedded limestone with shale seams and quartzitic bands, with a great number of quartz veins.

Dark gray shales with brecciated limestone pebbles, the beds reaching 200 feet or more (assuming no repetition) in section given on page 81, are exposed at the west edge of the Bald mountain quarry and in the sections north of it. They are interfolded with the Bald Mountain limestone and Rysedorph Hill conglomerate, but have the appearance of the Schodack beds, and are probably Georgian beds forced into the Ordovicic belt near the overthrust plane.

SCHAGHTICOKE SHALE

The Schaghticoke shale with its characteristic faunule, consisting of *Dictyonema flabelliforme* and *Staurograptus dichotomus* Emmons var. *apertus* Ruedemann was discovered by us in a cut of the Hudson Valley Railroad, near the mill of the Standard Wall Paper Company about a mile north of Schuylerville, and thence traced across the lower part of the rapids of the Hudson below Thomson. The entire belt is probably not more than 1000 feet wide and bounded on both sides by outcrops of Normanskill shale; its length is unknown since it runs in both directions under the drift. The rock in the exposure is much contorted and consists for the most part of light greenish gray, glazed argillaceous shale that weathers to a light drab or whitish color with intercalations of coarser light bluish gray more or less sandy mud shale and small streaks of black shale containing the graptolites. It also contains a 3½ feet bed of coarse grit with black calcareous and argillaceous pebbles and large, floating, rounded sand grains. One part of the formation is characterized by a number of calcareous sandstone beds ⅛ to 1 foot thick, which weather into a characteristic chestnut-brown sandy crust. Through the contortions of the beds these rocks are mostly broken into strings of brown boulderlike blocks.

In the river bed where the beds are seen on edge, they appear as greenish gray shales with frequent black shale bands and brown calcareous sandstone beds and some thicker beds of argillaceous mudrock.

These Schaghticoke shales of Schuylerville very much resemble in the alternation of the greenish gray and black argillaceous shales, giving the outcrops on edge a very characteristic banded appearance, the typical Schaghticoke shale as described by the author from the bed of the Hoosic river at Schaghticoke, lacking, however, the intercalated thin limestone bands observed there. They are distinguished from the surrounding Normanskill shale by the absence of white-weathering chert layers and the presence of the chocolate-brown weathering calcareous sandstone; but of course none of these criteria is sufficient to recognize them without the fossil evidence. It is for this reason that they may be outcropping in other localities without having been recognized.

When the author described the Dictyonema flabelliforme or Schaghticoke shale,[1] he followed the consensus of the preceding European authors who considered the shale with Dictyonema flabelliforme as marking the top of the Cambric. Since that time stratigraphers have, especially in Sweden, advanced arguments for placing the Dictyonema bed at the base of the Ordovicic, a proceeding which would also seem to agree well with the condition in the slate belt, since the Dictyonema shale is on one hand separated by a great hiatus from the underlying Georgic, but on the other by its lithologic character and probably also stratigraphically is closely connected with the following Deep Kill shales. Lately Ulrich[2] has also argued for the close stratigraphic connection of the Dictyonema flabelliforme zone with the Tetragraptus zone (the lowest of the Deep Kill zones), and placed the Dictyonema flabelliforme zone in his Canadian system (which comprises the Tribes Hill limestone and Beekmantown B-E).

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[1] Ruedemann, R. Cambric Dictyonema Fauna in the Slate Belt of Eastern New York. Pal. Rep't (for 1902) 1903, p. 934.

[2] Ulrich, E. O. Revision of the Paleozoic Systems, pts 1–3. Geol. Soc. Amer. Bul., v. 22, no. 3, p. 678.

DEEP KILL SHALE

The Deep Kill shale has not been recognized anywhere on the two quadrangles, but since it lies in the stratigraphical series between the Schaghticoke and Normanskill shales, it is quite possible that small parts of this formation, like that here observed of the Schaghticoke shale, may have been forced up through the extremely disturbed belt of Normanskill shales. Also in this case, the finding of the characteristic graptolites would furnish the only conclusive evidence of its presence, although the lithologic characters of the Deep Kill shale are such that where well exposed they are readily recognized.

BALD MOUNTAIN LIMESTONE [1]

At the western foot of Louse hill near the southwestern corner of the Georgian area, a belt of dolomite and limestone appears on the surface. It can thence be traced northward for about a mile, when it disappears under drift but its presence below the latter is still indicated through the frequent limestone boulders in the drift seen in the stone fences. It then is again well exposed in the ridge skirting the west bank of the Batten kill at its bend south of Middle Falls, in the village of Middle Falls where it causes the fall in the river, and north of Middle Falls in many hillocks protruding through the drift on both sides of the road from Middle Falls to Bald mountain. An excellent locality rich in fossils was found by the writer in an abandoned quarry on the north bank of the Batten kill a quarter of a mile above the village. In front of Bald mountain the beds are now best exposed by the large quarry operations which were carried on there formerly to supply the material for two limekilns still standing west of the road skirting the mountain on the west. From Bald mountain the beds are traceable but half a mile as indicated on the map, but may reappear farther north beyond the limits of the sheet. Southward of Louse hill, this belt fails completely on the west edge of the Georgian in Washington and Rensselaer counties.

This limestone belt is in the neighborhood of Bald mountain, that is at the Bald mountain quarries and northward accompanied by a conglomerate which we have identified with the Rysedorph

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[1] Grabau in his paper on the Physical and Faunal Evolution of North America during Ordovicic, etc. Time (Jour. of Geol. 1909) cites a "Bald Mt" formation in the correlation table I, p. 251, but on reference to the text (p. 235) it is seen that the "Bald Eagle (Mountain)" conglomerate is meant.

Hill conglomerate, described by the writer from the neighborhood of Albany (see page 80).

This belt was probably first noted by Emmons who indicated it on his map accompanying his Agricultural Report[1] and gave a section through Bald mountain in his paper on the Taconic series in the same report. He identified it with the " Calciferous sandstone " (Beekmantown), distinguishing a blue portion of purer limestone and a lighter one. He included, however, the thin-bedded limestone on top of the mountain in the " Calciferous sandrock." This latter has been shown by Walcott (*op. cit.,* page 317) to be of Cambric (Georgian) age, a fault separating the Georgian rocks from the limestone belt (see chapter on structure of Bald mountain, page 108). Walcott, who first correctly separated on a map the Ordovicic and Lower Cambric areas of the slate belt (*op. cit.,* plate 3), also indicated the extension of the limestone belt and gave a section of Bald mountain in which he distinguished " Calciferous sandrock " (the lower darker rock) separated by dark shales from " Chazy limestone." From a locality (*op. cit.,* page 317) about 2 miles north of Bald mountain, Trenton fossils (Dalmanella testudinaria, Rafinesquina alternata, Maclurea and other gastropods, Calymmene senaria and fragments of Asaphus platycephalus) are cited. It is thus seen that Walcott held the view that the limestone belt contains Calciferous, Chazy and Trenton rocks, a view also expressed on plate 3. Dale has on his map of the slate belt (1899, plate 13) distinguished the limestones simply as lower Siluric (Ordovicic) limestone from the Lower Siluric shale, etc., stating (page 190) : " The Trenton limestone occurs sporadically within the Ordovician areas of the slate belt; also on its western edge in Argyle and in Hartford. In some places it was probably deposited contemporaneously with the Hudson grit and shales, or it may underlie a portion of them. In others it may represent the entire Lower Silurian series and should then be regarded as Trenton, Chazy and Calciferous."

We see from this quotation that the determinations of the age of the Ordovicic limestone in the slate belt are rather insecure, a fact that can be readily explained by the scarcity and poor preservation of the fossils usually obtained there.

On the Geologic Map of New York, published by F. J. H. Merrill (1901), the limestone belt on the west edge of the Georgian is entered simply as Trenton.

[1] Emmons, Ebenezer. Agriculture of New York, v. 1, 1846.

As far as the part of the limestone belt on the Schuylerville sheet is concerned, our collections have shown that one must there sharply distinguish between the dolomite and limestone on one hand, and the conglomerate on the other, for the former have only furnished fossils of Beekmantown age, and the latter such indicating Black river to Trenton age.

The principal fossiliferous outcrops of the limestones are found in the neighborhood of Middle Falls. The most important one is an old quarry, one-quarter of a mile above the village at the bend of the river, where about 25 feet of highly fossiliferous limestone are exposed. This locality has furnished:

Cryptozoon *sp.*
Girvanella *sp.*
Undescribed sponges
Eccyliopterus planidorsalis *Ulrich* MS
E. planibasalis *Ulrich* MS
Oxydiscus *sp. nov.*
Hormotoma? (Murchisonia) cassina (*Whitfield*), section
Segments of trilobites

A small knoll at the northern outskirt of Middle Falls was found to contain specimens of

Polytoechia apicalis (*Whitfield*)
cf. Protorthis minima *Whitfield*

Along the road from Middle Falls to Bald mountain, dolomite and limestone outcrops are observed on both sides; one of these, west of the road and halfway between Bald mountain and Middle Falls, contained in the limestone, ostracods (undescribed species of Primitia and Leperditia) and fragments of trilobites.

The limestone of the Bald mountain quarry contains cephalopods and gastropods, namely:

Cryptozoon *sp.*
Eccyliopterus planidorsalis *Ulrich* MS
E. planibasalis *Ulrich* MS
Liospira? *sp.* (section)
Cameroceras brainerdi (*Whitfield*)
Cyrtoceras confertissimum *Whitfield*

Cephalopod and gastropod sections were also observed in a small quarry on the roadside at the west foot of Louse hill.

These faunules demonstrate the Beekmantown age of the limestone and indicate that it is to be correlated roughly to the Fort Cassin beds, which correspond to unknown parts of Brainerd & Seely's divisions D and E. Since, however, this belt of Beekmantown rocks fully corresponds to the Fort Cassin beds, neither in its lithology nor in its faunal aspect or its stratigraphy, we consider it unsafe to correlate it with the Fort Cassin and shall designate the beds as *Bald Mountain* limestone.

The fauna of the Bald Mountain limestone is distinct from the Fort Cassin fauna, on the one hand in the entire absence of the coiled nautiloid cephalopods so characteristic of that fauna, and, on the other hand, by the prevalence of striking Eccyliopteri, which, according to Ulrich, are identical with forms occurring in the Canadian of Missouri.

The Bald Mountain limestone can neither be correlated nor be continuous with the limestones and dolomites outcropping at the foot of the Adirondacks only a short distance to the west on the Saratoga quadrangle, since these beds, though formerly referred to the Calciferous or Beekmantown, are now known to represent only the lowest division A, and perhaps part of B, which are separated by a great unconformity from the Beekmantown and are claimed even to belong to another system (Ozarkic of Ulrich). It is possible that the Bald Mountain limestone finds its continuation 80 miles farther south in the Wappinger limestone in southeastern New York, but the latter belt includes limestones of Hoyt, Beekmantown, and Mohawkian ages, and the name is therefore not applicable to the possible northern continuation of its Beekmantown portion.

The lower part of this formation consists of dark gray (but sandy gray when weathered), massive, often sandy and also brecciated, practically barren dolomite[1] of which we have seen 40 feet or more, some in beds as much as 6 feet thick. It is well seen in several places, namely, an old quarry on the west bank of the Batten kill half a mile south of Middle Falls, in an abandoned quarry on a hill at the west foot of Louse hill 2¼ miles south of Middle Falls and in a quarry by the road south of Bald mountain. This, like all the limestone and dolomite on Bald mountain, is referred to the Calciferous by Emmons and it is the Calciferous sandrock of Walcott's Bald Mountain section. It is in the neighborhood of Bald

[1] A few sections suggestive of cephalopods and Ophileta were observed in calcareous layers.

mountain now best exposed near the two road crossings, the one just west and the other just south of Bald mountain, near the latter crossing in a quarry. The dolomite in the former outcrop is, on account of the complicated overturned and recumbent fold structure of the limestone belt, apparently separated from the limestone by shale beds (see page 109) and so represented by Walcott. The aspect of the dolomite which also contains considerable chert reminds one of the Little Falls dolomite. It is, however, not to be separated as a unit from the limestone, for the two were found to be grading into each other on the road from Middle Falls to Bald mountain and also along the road south of Middle Falls. One instructive locality, a small quarry alongside the road, at the west foot of Louse hill, furnished the following section in descending order:

Thin-bedded limestone	4 feet
Massive limestone bed	3½ feet
Brecciated limestone with gastropods	3 feet
Dolomite bed with irregular band of limestone in middle, full of narrow chambered cephalopods	2 feet, 4 inches
Dolomite bed	1 foot, 2 inches
Brecciated limestone	3 feet

Of the limestone we have seen in one place (west of Louse hill) 70 feet in continuous section, with the top and bottom not exposed. It may therefore reach 100 feet in thickness. It is for the most part fine grained, sometimes approaching the dove-colored limestones, light bluish gray in color with many white crystalline spots. In the lower part it contains somewhat arenaceous bands. It resembles some of the limestone of D of the Champlain valley and also some of the Middle Chazy rocks. Emmons referred it to the Calciferous sandrock (Beekmantown). Walcott designated it as Chazy limestone in the Bald Mountain section, but stated (1888, page 317) that about 2 miles north of Bald mountain similar rocks contain Trenton fossils. Dale (1889, page 190) also refers to this limestone as Trenton limestone but mentions that in some places it may represent the entire Lower Siluric series and should then be regarded as Trenton, Chazy, and Calciferous. On the Schuylerville quadrangle the limestone is as the above given fossil lists show, throughout of Beekmantown age. There is, however, no doubt that also in other parts of the slate belt limestone of Trenton, or at least Mohawkian, age outcrops. The presence of such is also indicated by the Rysedorph Hill conglomerate, occurring at Bald mountain with its Mohawkian fauna.

The stratigraphic relation of the Bald Mountain limestone to the shales is nowhere apparent, the observed contacts between the two being along fault planes. Thus the limestone is seen to rest by a westerly rising plane on the folded Snake Hill shales below the falls at Middle Falls; since the shales are younger than the limestone, the latter is here overthrust on the shale. The interbedding of shale between the dolomite and shale, assumed in Walcott's Bald Mountain section, is due to a mass of shale folded or thrust locally into the Bald Mountain limestone. The limestone belt is on one side bounded by the shale, on the other by the Georgian rocks; and, as a glance at the map will show, it ends abruptly where the edge of the Georgian overthrust blanket southwest of Louse hill turns east, suggesting that this overthrust mass brought the limestone with it (see postea page 110). We have thus, principally from the fossil evidence, to assume that the Bald Mountain limestone, which surely is older than the Normanskill shale, overlies the Deep Kill shale. But it may come from an entirely different trough or basin, that originally was east of the Levis trough.

RYSEDORPH HILL CONGLOMERATE

Associated with the Bald Mountain limestone in the Bald Mountain section and for 2 miles north of it, occurs a conglomerate of striking character. It is best exposed at the north end of the Bald Mountain quarry, and along the brook skirting the north side of the mountain, below the road. The rock consists of a black mud matrix. In it float without assortment pebbles of all sizes, from that of a pea to those 2 to 3 feet in diameter. The smaller pebbles are well rounded, the larger ones subangular with rounded edges. They are in part the Georgian limestone, but also deep blue dolomite and gray and dove limestones. A few of the pebbles have furnished fragmentary fossils which indicate the Trenton age of these pebbles. The fossils were:

Lingula sp. (fragment)
Siphonotreta cf. minnesotensis *Hall & Clarke*
Rafinesquina sp. (fragment)
Plectambonites pisum *Ruedemann*
Ceraurus cf. pleurexanthemus (*Green*), fragment
Bythocypris cylindrica (*Hall*)
Isochilina armata *Walcott* var. pygmaea *Ruedemann*

In the matrix there was also obtained a specimen of Plectambonites pisum, a species known from the Rysedorph Hill conglomerate at Rysedorph hill. As this conglomerate contains pebbles of various ages, from the Georgian to the Mohawkian, like that of Rysedorph hill, and lies in the northern continuation of the latter and apparently, also as this latter, above or in the upper Normanskill shale, we have identified the Bald Mountain conglomerate with the Rysedorph Hill conglomerate.[1] The occurrence of Plectambonites pisum common to both outcrops also supports this view.

We surmise that the Trenton fossils formerly recorded from the limestone north of Bald mountain came from this conglomerate.

The conglomerate at Bald mountain may reach a considerable thickness; in the quarry it is in one place over 20 feet thick, but it is impossible to say how much the folded condition contributes to this thickness. Along the brook northwest of Bald mountain we observed the following section from east to west, the beds being nearly all vertical:

1	Cambric shale	
2	Covered	90 feet
3	Limestone with some quartzite and breccia	55 feet
4	Covered	270 feet
5	Conglomerate with large pebbles Trenton fossils and calcareous matrix Rysedorph Hill conglomerate	45 feet
6	Calcareous shale and shaly nodular limestone (Georgian)	200 feet
7	Covered	70 feet
8	Conglomerate with large pebbles	75 feet
9	Covered	

It is possible that the conglomerate bed in no. 8 is folded upon itself, and in no. 5 the simple thickness of the bed is exposed. It is there about 45 feet thick.

While this conglomerate in its outcrops adjoins the Bald Mountain limestone, its fossils indicate that it is younger than the typical Normanskill shale and intervenes in age between this and the Snake Hill shale. It therefore should be separated from the Bald Mountain limestone by the Normanskill shale. On Rysedorph hill the

[1] Ruedemann, R. Trenton Conglomerate of Rysedorph hill. N. Y. State Mus. Bul. 49, p. 3.

conglomerate also outcrops so near the overthrust fault of the Georgian that it might well be a block caught in the fault, although it is there underlain and overlain by shale of presumably Normanskill age. At the Moordener kill a few miles south from Rysedorph hill, it is seen five times repeated in the section and apparently folded in with Normanskill shales 1 to 2 miles away from the overthrust fault. Another fine exposure of this conglomerate which also has furnished Plectambonites pisum is seen in the shore cliffs at Papscanee island, about 5 miles below Albany. This outcrop[1] is at least 2 miles away from the overthrust plane, and another good exposure at Schodack Landing is equally distant. The typical Rysedorph Hill conglomerate southeast of Albany is thus too far away from the thrust fault on which the Georgian was brought westward to be considered as having been brought along this plane, and it is seen in a number of places clearly intercalated in the Normanskill shale as an intraformational conglomerate.

Whatever may be the origin of this remarkable rock, the character and variety of the pebbles and the character of their faunules indicate, as we have shown in the paper on the Rysedorph Hill conglomerate, that they are derived from beds not now exposed in the slate belt and probably brought from the east, especially since the fossils are of Atlantic type. The age of the conglomerate which in museum Bulletin 42 had been held to be lower to middle Trenton, is from the aspect of the faunules of both the youngest pebbles and the matrix, probably greater and corresponding to the Black river. The Normanskill shale with which it is associated in the Rysedorph hill and Moordener kill localities, has been found by Ulrich in the Athens trough to be upper Chazyan in age. We have therefore considered the conglomerate as originally overlying the Normanskill shale and thus represented it in the diagram, text figure 15. Investigations, however, carried on since have brought out the fact that the Normanskill shale embraces two formations, as is more fully stated below (page 93) and that the Rysedorph Hill conglomerate is intercalated in the upper division of Black River age.

The peculiar fauna which was described from this conglomerate by the writer has been recognized in part in the Chambersburg limestone of Pennsylvania of the Chambersburg-Massanutten and

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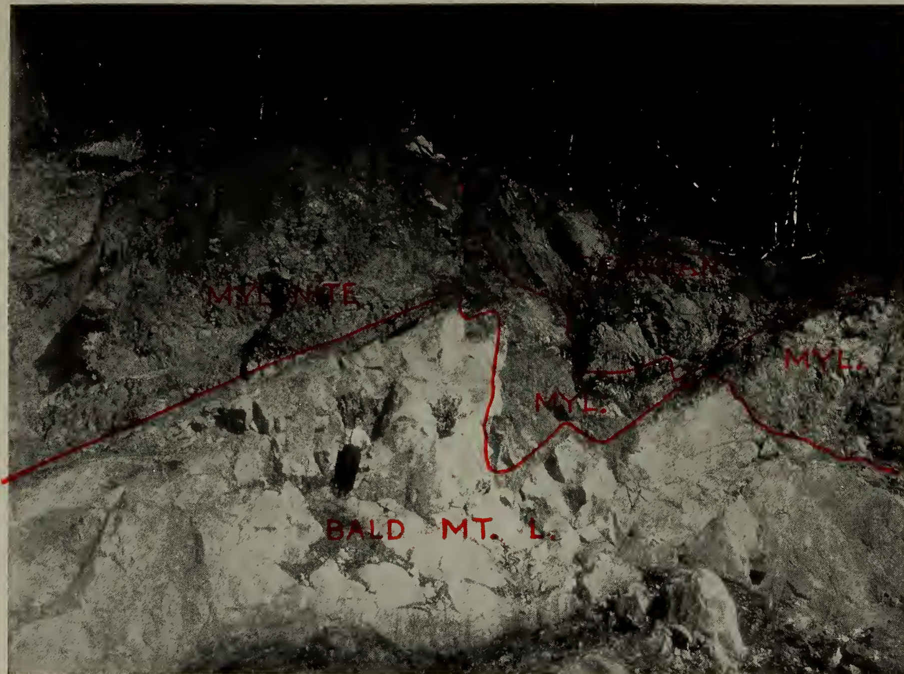
[1] This exposure while then known to the author, was accidentally omitted in Bulletin 42.

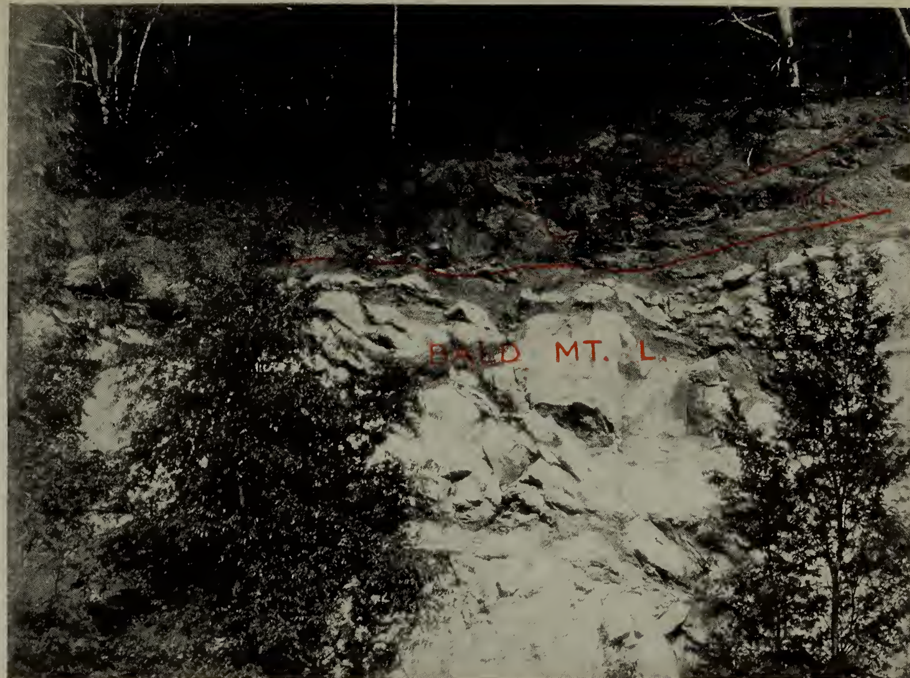
Plate 12



R. Ruedemann, photo, 1911

View in northern part of western face of Bald Mountain quarry, showing the Bald Mountain limestone, overlain by irregular masses of mylonite or fault-brecciated material and Georgian.

Plate 13



R. Ruedemann, photo, 1911

View of southern part of western face of Bald Mountain quarry, showing the Bald Mountain limestone overlain by a sheet of mylonite on which in turn rest Georgian rocks that in the quarry, through their red-brown color, contrast more sharply with the black fault-breccia than in the photograph. The uppermost beds of the Bald Mountain limestone are seen to be torn into strings of blocks as if in the process of being incorporated into the breccia.

Plate 14

R. Ruedemann, photo, 1911

View in the southern face of the Bald Mountain quarry, showing the irregular faulted and broken cliffs of Bald Mountain limestone projecting into a thick mass of mylonite which carries a continuous blanket of much crumpled Georgian grit beds (Bomoseen beds)

Mercersburg troughs and farther south.[1] Since, however, the Chambersburg limestone does not continue in the Levis trough north of Pennsylvania, the conglomerate can not be referred to as constituting a northern continuation or a part of the Chambersburg limestone and it appears that the Atlantic fauna found in the Rysedorph Hill conglomerate was able to enter the troughs between the Appalachian barriers from the east in several independent places.

The conglomerate about Bald mountain, which is here correlated with the Rysedorph Hill conglomerate is clearly bound to the large overthrust plane, for at Bald mountain itself it is associated with the Bald Mountain limestone, and to the north of it it is even infolded with Georgian shales. As we have already stated, it is here exposed only close to the great overthrust fault and by the latter brought in juxtaposition with the Bald Mountain limestone and Georgian rocks. This position is probably due to its greater resistant power as compared with that of the softer shales, which have been ground up.

Besides this conglomerate, the matrix of which consists, as at Rysedorph hill, largely of sandy lime, there is observed at Bald mountain a breccia of remarkable appearance and thickness. This is seen in plates 12–14 between the Bald Mountain limestone and the Georgian in very irregular masses. It is best exposed on the south face of the quarry, where it reaches 30 feet in thickness in one place and can be easily studied since it descends to the bottom of the quarry. It consists here of an utterly unstratified black mud matrix with numerous unassorted small more or less angular pieces, mostly of the size of a pea or smaller, of limestone, olive grit, chert etc. (see plate 15, which is a photo of a hand specimen). The matrix has the appearance of a thoroughly ground up shale mass and with pebbles floating in it, resembles a tillite. There is, however, no doubt that this mass is the result of the tremendous friction at the base and between the masses of Georgian rocks on top and the Bald Mountain limestone below, which were moved on a nearly horizontal plane. How the top beds of the Bald mountain limestone were torn off and incorporated in the shale is well shown in plate 13, where strings of Bald Mountain limestone are seen to reach into the black mudrock in the process of being torn up. The black soft

[1] Stose, G. W., Mercersburg-Chambersburg folio, Pa. U. S. Geol. Surv., folio 170, 1909. Bassler, R. S., The Cement Resources of Virginia, West of the Blue Ridge. Va. Geol. Surv. Bul. 2, 1909. Ulrich, E. O., Revision of the Paleozoic Systems, pts. 1–3. Geol. Soc. Amer. Bul. v. 22, no. 3. 1911.

mudrock is the result of the grinding up of the black Georgian shale and of Snake Hill and Normanskill shales on both sides of the thrust fault.

Törnebohm (1896) has first shown how the rocks are ground into flour along the great overthrust planes. He terms this flour "Friktionsbrei" (mylonite) stating that it served as "Schmiermittel" (lubricating substance) during the overthrusting and that its thickness depends on the obstacles in the mass that is overridden. In the French central plateau these masses are said to reach several hundred meters in thickness.

That in Bald mountain the conditions that rest in the resistance of the underground were especially favorable for the accumulation of the mylonite, is distinctly shown by the bulging up of the Bald mountain limestone mass there, the limestone, together with the overlying Georgian rocks, descending north and south of the face of the Bald mountain quarry, away from the mountain.

THE NORMANSKILL SHALE

This graptolite shale which has received its name from the exposure at the Normans kill at Albany, forms two belts on the Schuylerville quadrangle, one, entirely surrounded by Snake Hill beds, coming up from the Cohoes quadrangle and terminating near the mouth of the Batten kill, and another south of the Georgian overthrust mass, culminating in Willard mountain.

As in the entire shale belt in the Hudson River valley, the greater part of the Normanskill formation consists of blue to gray, mostly argillaceous, often more or less sandy shales, with thin intercalations of black, highly carbonaceous graptolitiferous and frequently pyritiferous shales; the lighter bluish gray and black shales often giving the rock a banded appearance in the common edgewise view.

Where these shales are brought up from such depths that they are still fresh and unaffected by surface weathering and frost, they appear quite different, as more or less compact bluish gray and black mudrocks. Considerable material of this character was seen at the new canal locks above Schuylerville and in other places.

The shales of the Normanskill formation include, however, two other kinds of rock in such quantities that their frequent appearance in outcrops can be considered as quite characteristic of the formation. These are the "white weathering cherty beds" and the grit.

H. P. Whitlock, photo

Hand specimen of mylonite from Bald Mountain quarry, showing the compact structure of the argillaceous matrix, with the numerous small fragments of limestone and dolomite floating in it and seen on the weathered surface. On the left an obscure cleavage is seen. Natural size.

H. G. Whitlock, photo

Specimen of Lower Cambric rock from the top of the south face of the Bald Mountain quarry. The upper view shows the small slip faults producing offsets on the bedding plane that appear as broader light bands in the photograph.

The lower view shows the other side of the same slab; it is so illuminated that the numerous small ripples parallel with the fault planes are seen. They result from the shoving of the specimen in the overthrusting along a plane oblique to the bedding plane which forms the surface of the slab. Both views reduced one-fifth.

The white weathering cherty beds. Associated with the black shales of the Normanskill formation occurs a series of very hard, splintery, dark to light greenish or black, cherty-looking beds which weather with very light gray or white crust. These siliceous beds frequently through their greater hardness, stand out as white ridges and form characteristic landmarks. According to Dale (*op. cit.,* page 186) the white surface gives the reaction for kaolinite[1] and the rock was probably originally a feldspathic mud, with quartz fragments and muscovite scales; the latter two appearing under the microscope as the principal constituents of the cherty beds.

The finding of Normanskill graptolites in the white beds at several places on the Schuylerville sheet, notably in a small creek just above Coveville and northeast of Willard mountain, leave no doubt of the Normanskill age of the principal mass of the cherty beds. There is, however, no doubt that similar cherty layers occur also, though rarely, in the Snake Hill formation and that all transitions occur from the common argillaceous shales through slightly more siliceous and whitish weathering shales to the thick-bedded, white-weathering cherty layers.

On account of their great hardness the white beds most frequently form the tops of ridges and can often be traced for some distance along the strike of the folded beds. The more important outcrops of white beds have been indicated on the map by the blue symbols. These show that the principal areas of chert outcrops are the region extending from Coveville northward to Thomson and Northumberland and that of the Willard mountain ridge in the southeast corner of the quadrangle. In the former the most striking chert ridge is seen 1½ miles west of Victory Mills. This forms cliffs seen from the Schuylerville branch of the Fitchburg Railroad, in which are solid beds of the cherty or siliceous rock 30 feet and more thick. Other smaller ridges of white beds protrude through the drift one-half of a mile west of Victory Mills and on the water-swept plateau north of Coveville. Also south and north of the Northumberland plug appear ledges of the harder cherty beds on the hillsides and a small outcrop of very thick-bedded, deep black chert was found just west of the entrance of the Hudson river bridge at Thomson.

[1]According to a later statement by the same author (1904, p. 36) the weathering white of the chert may be due either to the loss of carbon or to the kaolinization of a fine feldspathic cement.

The other belt of thick and prominent outcrops of white-weathering cherty beds extends across Willard mountain and forms the backbone or top of the high ridge extending north from Willard mountain, obviously one of the causes that this steep landmark has withstood weathering so much better than the surrounding land. On top of Willard mountain itself, a ridge about 150 feet wide of white-weathering, vertical or steeply inclined synclinal beds is found. The high cliffs on the west brow of Willard mountain consist principally of this chert, which is again finely exposed on the road crossing the ridge north of Willard mountain. It extends here along the crest of the ridge to the north point. Another ledge strikes about a mile east of Willard mountain.

A ridge of white beds begins also north of Snake hill at the shore of Saratoga lake and can be recognized again 2 to 3 miles farther northeast. At the lake shore a solid 3 foot bed of black chert was found intercalated in fissile dark shales. This chert contained Climacograptus bicornis, Glossograptus, Climacograptus modestus, but not the Dicellograptus nicholsoni that occurs all along the lake shore in the shales. It would thus seem to be also of Normanskill age, although it is surrounded by Snake Hill beds. Farther northeast a thickness of over 20 feet of this chert has been observed on top of the ridge.

The graptolites in the chert are not preserved as carbonaceous or pyritized remains as in the argillaceous shales, but are as white as the weathered surface of the rock and, wherever present, show a striking contrast with the dark rock. It is possible that they are also kaolinized, but they may also be composed of the mineral gümbelite, a greenish white silicate which has been found in Bavaria to have sometimes replaced the carbonaceous tests of graptolites.

The Normanskill grit. The white-weathering chert beds are always associated, on the Schuylerville quadrangle at least, with the Normanskill grit. As in the case of the cherty beds, grit beds are also present, though in much less development, in the Snake Hill formation. These grits of both formations have been carefully described as Hudson grit by Dale (1899, page 187), from whom we quote:

The Hudson grit is a rock so marked in its characteristics as to be easily identified. It is coarse, grayish, sandy looking. Fresh fracture surfaces are very dark and show glistening glassy quartz grains and very frequently minute, pale, greenish, slaty particles. Under the miscroscope, it consists of angular grains of quartz, orthoclase, plagioclase, and scales of muscovite, probably clastic. The cement contains not a little carbonaceous matter, secondary calcite, and pyrite. In the more easterly Ordovician area the cement is quite sericitic and the feldspar is partially sericitized, but in other places and along the Hudson, in Rensselaer county, the amount of sericite in the cement is small. The marked features are the heterogeneity of the fragments, their irregular size, angular outline, and usually the absence of any arrangement in them. Chlorite is rarely present.

A further peculiarity of the Hudson grits is that they contain particles of various fragmental rocks, showing that they were derived from the erosion not only of older granites and gneisses, but of sedimentary rocks of Ordovician or pre-Ordovician age. The particles of clastic rocks were found to consist of shale, micaceous quartzite, calcareous quartzite, limestone or dolomite, slate and flint. The most abundant were found to be quartzite, slate and shale.

Dale recorded the occurrence of graptolites of the Normanskill horizon from the shales interbedded in the Hudson grits.

Like the white beds, the grit beds of the Normanskill shale come to the surface on the Schuylerville quadrangle in two well-circumscribed areas. The grit ledges on this map are denoted by the brown symbol and are crowded in the region west and north of Quaker Springs and about Willard mountain. The former region is one of extremely rough topography, owing to the many broken edges of the grit beds in the closed synclines and anticlines. It is for this reason locally known as " The rocky tucks " and was formerly the site of considerable quarrying for sills and building stone. The ledges are especially well seen in the neighborhood of Quaker Springs. The interbedded shale is but rarely seen, since it usually has weathered back too far and is covered by drift. In one place, at least, we found graptolites of Normanskill type in the interbedded shale. The grit itself is barren of fossils, a few joints of crinoid stems being the only traces of fossils observed.

The belt of grit ledges ends rather abruptly about a mile south of Gates, or 2 miles south of the north bend of Fish creek, not to reappear farther north on the quadrangle.

The second region of grit outcrops is the Willard mountain ridge. As we noted before, the top of this very prominent ridge is formed by the white-weathering cherty beds; the flanks consist, however, of the Normanskill grit. The grit ledges appear very prominently along the lower road west of the mountain. They form considerable cliffs on the northwest side of the Willard ridge and are observable in outcrops and cliffs along the road skirting the eastern foot of the mountain. This belt also terminates abruptly against the Georgian rocks of Louse hill, which have overridden its northern continuation in the over-thrust movement.

The boundaries between the grit zone, shale zone and white-chert bed zone are not sharply delimited, and in one place all three were found to alternate in typical beds several times in a thickness of 17 feet. As the coarse clastic material in the grit indicates, shallow marine conditions prevailed at times during the deposition of the beds and the supply of siliceous and argillaceous mud changed at times very rapidly.

The true stratigraphic relation of the shales, white-weathering beds and grit, owing to the intensely folded and faulted condition of the region, is nowhere shown conclusively. Dale in 1899 (chart facing page 178) gave the following succession in descending order: *Ig* Hudson grits, *Hw* Hudson white beds, *G* Hudson shales; placing the grits on top of the series. In 1904 (page 37) however, he published the following table showing the Hudson formation as exposed in Rensselaer county and the northeastern part of Columbia county, N. Y.:

DESCRIPTION OF STRATA	FAUNA	ESTIMATED THICKNESS IN FEET
1 Black shale with arenaceous limestone (Ruedemann's stations 24–26)	Diplograptus amplexicaulis	1200–2500?
2 Black and gray shale with interbedded grit	Normanskill graptolite fauna	
3 Similar shale with limestone and limestone conglomerate	Trenton fauna in limestone and cement of conglomerate	
4 Black, siliceous, white-weathering, cherty-looking shale		
5 Reddish, purplish, greenish shale with small quartzite bands		

Number 1 are the beds here described as the Snake Hill formation, and no. 3 those here referred to the Rysedorph Hill conglomerate, and placed now, on faunal evidence, above or near the top of the Normanskill beds; while no. 5, the colored shales, are not exposed, if present, on the Schuylerville quadrangle. It will be seen that here the grits are also placed above the white beds, while the dark shales are not recognized as a separate subdivision.

It is stated in a footnote that "the vertical relations of the colored shale and the black siliceous shale to each other and to the black and gray shale with Normanskill graptolites are not clear. They are all intimately associated." The same condition prevails farther north in the Schuylerville quadrangle. The facts which are here available for the discussion of the succession of the three divisions are, first, the arrangement in belts from west to east, and second, the structure of Willard mountain. The arrangement of the belts from west to east, with the grits as the westernmost part and the white beds following, would suggest that the grits are the youngest division, since they are nearest to the overlying Snake Hill beds. We have found in general in the shale belt, where larger faults or folds interfere, that the westernmost beds of the same zone are frequently the younger. On the other hand, the Willard mountain ridge is capped by the white beds and the mass of the mountain consists of grits, which dip east on the west side and west on the east side, indicating a more or less complex synclinal structure of the mountain and a normal position of the white beds above the grits.

In weighing the evidence from the two facts, the arrangement of the belts and the Willard mountain section against each other, we incline to consider the latter as nearer the truth, for the abrupt ending of the grit belt near Fish creek proves that the boundary line between the Normanskill and the Snake Hill formations is probably not one of simple succession, but the result of overthrusting and folding, the grit belt being faulted out north of Fish creek. The position of the grit next to the Snake Hill beds is then no evidence for the stratigraphic position of the grit nearest to the Snake Hill formation. Moreover we have good reasons for believing that in the normal succession the Rysedorph Hill conglomerate is located high up in the Normanskill. Its absence near the areal boundary on the quadrangle between the two is then further evidence of the diastrophic rather than stratigraphic character of that line.

We infer from a remark of Dale's[1] that he would have placed

[1] 1899, p. 294. Dale states: "The presence near the base of the Ordovician of a mass of grit containing fragments of slate, limestone and quartzite * * * points plainly to some unconformity at that time. The chief objection to inferring from the particles of clastic rocks in the grits, an unconformity between the Cambrian and Ordovician, is that these grits do not always occur at the contact with undoubted Cambrian rocks."

the grit at the base were it not for the fact that it is not always in contact with the Georgian. But this fact, since we now know that the Georgian and the Ordovicic are in many, or all, places separated by an overthrust plane, is no longer of decisive value. On *a priori* ground, since there is an important unconformity in the slate region between the Lower Cambric Georgian rocks and the overlying Ordovicic beds, marking a long period of emergence and erosion, we should expect the Ordovicic series to begin with the coarse grits, these being followed by the fine siliceous muds that produced the white beds, and the latter again by the argillaceous muds that become the dark graptolite shales. This succession agrees with the Willard mountain section and appears to us the true one.

Another question which can not be satisfactorily answered is that of the thickness of the Normanskill formation and of its divisions in this region. Dale, in the above-mentioned table, assigns the "Hudson shales" a thickness of 50+ feet; the "Hudson white beds" 400 feet or less and to the "Hudson grits" 500+ feet; and in a later paper (1904, page 37) the "Hudson formation" of Rensselaer county (including the Snake Hill beds and colored shales) is estimated at 1200 to 2500? feet. A former estimate for the Hudson formation on the east side of the Hudson river by Walcott (1890, page 346) had been 5000 feet. This, as well as Ashburner's estimate of 3500 feet for the Altamont well, are considered by Dale as too high, who holds that "in a region of such moderate relief a mass of beds 2500 feet thick,[1] thrown into small, close and mostly overturned folds, would account for such a rock surface as that depicted in that portion of the map which lies west of the Taconic range." While we agree with Dale in this latter view, we yet consider his estimates as giving the minimal estimates, rather than the maximal ones, for where the succession of faunules permitted the exclusion of the repetition of beds as a factor in increasing the apparent thickness of the formations, considerably greater thicknesses were obtained by the writer. In the case of the Deep Kill graptolite shales of Beekmantown age, for instance, the faunal zones indicate a thickness of the formation of from 200 to 300 feet, while Dale observed not more than 50 feet of this formation in any one place. It is true that Ashburner's measurement of 3500 feet in the Altamont well is not applicable to this shale region, because the shales at Altamont belong in another

[1] Dale's estimate of the combined thickness of the Lower Cambric and Lower Siluric in the slate belt.

basin and consist of Canajoharie, Schenectady and Indian Ladder shales. Nor can the great thickness of shales, passed in well-borings in the shale region itself, be considered as demonstrating a great thickness of the shales. In a well at Mechanicville, for instance, 1400 feet of shale were passed without reaching the bottom of the formation; since the shales there, however, are not only dipping at an average angle of about 70°, but also repeated in overturned folds, the thickness of the shale in the well is clearly no indication of a corresponding thickness of the shale beds.

That the possibility exists of great thickness of these shales in this region, however, is shown by the Canajoharie and Schenectady shales in the closely adjoining basin to the west, which were found to reach together more than 3000 feet in thickness.

On the western side of Willard mountain there are exposed about 400 feet of grits, probably without repetition of the beds, a thickness which fairly agrees with Dale's estimate. We would estimate as follows:

Grit.	500+ feet
White beds	400± feet
Shale.	100± feet

Fauna of the Normanskill beds. Faunules, mainly of graptolites, have been found in many places in the Normanskill belt on the Schuylerville quadrangle. We cite here only the more important occurrences which show the position of the grit, the white beds and shales in the Normanskill formation.

An outcrop of deep black shale, interbedded in the *grit* of the Rocky tucks, about 2 miles north of Quaker Springs, contained:

Corynoides gracilis *Hopkinson*
Didymograptus subtenuis (*Hall*)
Leptograptus *sp.*
Dicranograptus ramosus *Hall*
Climacograptus parvus *Hall*
C. scharenbergi *Lapworth*
Diplograptus cf. acutus *Lapworth*

This is a typical Normanskill association of species.

A six-foot bed of compact black *cherty rock* in a brook just above Coveville contained:

Dicranograptus ramosus *Hall*
Climacograptus parvus *Hall*

C. modestus *Ruedemann*
Retiograptus geinitzianus *Hall*

The black shale in a small railroad cut north of the Schuylerville station proved quite fossiliferous.[1] It has furnished:

Corynoides gracilis *Hopkinson*
Didymograptus subtenuis (*Hall*)
Leptograptus flaccidus *mut.* trentonensis *Rued.*
Dicranograptus ramosus *Hall*
Climacograptus bicornis *Hall*
C. parvus *Hall*
Graptospongia pusilla *Ruedemann*[2]
Leptobolus walcotti *Ruedemann*

This shale with its characteristic Normanskill fauna is intercalated in the white beds.

The shale and white beds abutting at the north and south against the Northumberland plug were found to contain Didymograptus sagittarius, showing that the plug is undoubtedly surrounded by Normanskill shale.

The black cherty band at Clarke's Mills mentioned above contains Climacograptus parvus, which also is restricted to the Normanskill shale.

Black shale, associated in the Willard mountain region with the white beds, contains:

Corynoides gracilis *Hopkinson*
Didymograptus sagitticaulis *Gurley*
Dicranograptus ramosus *Hall*
Dicellograptus sextans *Hall*
Cryptograptus tricornis (*Carruthers*)

and the white beds capping this mountain are hence also undoubtedly of Normanskill age.

A good Normanskill fauna was also collected in shales associated with the six-foot bed of chert on the east shore of Saratoga lake, namely:

Corynoides gracilis *Hopkinson*
Dicranograptus ramosus *Hall*

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[1] This locality was pointed out to the writer years ago by Prof. J. B. Woodworth.

[2] The originals of this sponge (described in N. Y. State Mus. Mem. 11, 1908, p. 485) came from this locality.

D. contortus *Ruedemann*
Climacograptus bicornis *Hall*
C. parvus *Hall*
C. putillus var. eximius *Ruedemann*
Glossograptus ciliatus *Emmons*
Lasiograptus bimucronatus (*Hall*)
Leptobolus *sp.*

Correlation. The writer, finding the Normanskill shale below beds with Diplograptus amplexicaulis, had inferred (1901) that it was at least as old or older than middle Trenton and correlated it with the middle and lower Trenton. It appears now from evidence obtained by Ulrich (op. cit. page 512) in the Athens trough, that the formation is still older and corresponds in age to the upper Chazy. But the Rysedorph Hill conglomerate of Black River age is intercalated in the Normanskill shale in a number of localities, some of which have been cited above (page 82) and to which may be added the fossiliferous exposure of the conglomerate in the big cut of the Boston & Albany Railroad south of Rensselaer.

These militating observations of the Chazy age of the Normanskill shale and of the intercalation of the Rysedorph Hill conglomerate of Black River age, appear to find their solution from observations made lately by the writer, leading to the inference that the Normanskill shale comprises two divisions or formations, the lower of which is of Chazy age and the upper of Black River age and possibly somewhat younger. This upper formation contains the Rysedorph Hill conglomerate. The inference of the subdivision of the Normanskill shale is based partly upon an unmistakable distinction in the graptolite faunules, indicating an older and a later horizon — to be worked out more fully when favorable sections present themselves — and partly upon the observation of traces of other fossils than graptolites and younger than Chazyan in age in the upper Normanskill shale.

SNAKE HILL BEDS

The Snake Hill formation occupies the southeast corner of the Saratoga quadrangle, from Ballston Spa and the Kayaderosseras creek to Saratoga lake. It crosses the Schuylerville quadrangle diagonally as a belt 4 to 5 miles wide, and a second eastern belt follows the Hudson river and unites with the western belt north of the Batten kill. These belts are segments of a greater belt that extends from Pennsylvania through southern New York along the

Hudson past Albany and Cohoes on to the Saratoga and Schuylerville quadrangles.

The formation was first distinguished by the writer from the "Hudson River formation" in the neighborhood of Albany (1901) and partly referred to as middle Trenton shale and partly as Utica shale and later correlated with the Magog shale of Canada. Mainly on account of the large and distinguishing faunas obtained around Albany, Green Island and Cohoes, and especially at Snake hill on the shore of Saratoga lake, the formation has recently (1912) been considered as a separate formation by the writer and named the *Snake Hill beds* from the most fossiliferous outcrop.

Lithologically, the formation is similar to the Normanskill beds, but it lacks the strong development of the grits and white beds as distinct divisions, though both are present in thinner intercalations. Besides it possesses a conglomerate with characters peculiar to itself. The preponderating portions of the formation, however, are dark gray to black, bluish and greenish gray argillaceous shales which are difficult of separation from the Normanskill shales, save by the inclosed faunas.

The argillaceous shales prevail so much in the Snake Hill formation that we have not observed in the belt in Albany county any grits and are aware of only one outcrop there with cherty-looking silicious shales. Also on the Schuylerville quadrangle the conglomerate, the grit and the cherty beds have been observed each only in a couple of outcrops, the rest all being soft shale. Thus, the large area in the northeast corner of the sheet, north of Moses kill, which has a rocky surface throughout, consists entirely of shale. The uniform composition of the formation of shale is also well shown in the new barge canal about Fort Miller, where half a mile of rock exposure exhibits nothing but dark gray shales.

Black, carbonaceous, graptolitiferous bands or seams are more frequently found than in the Normanskill shale, but they contain a much impoverished graptolite fauna as compared with that of the Normanskill formation. On the other hand, small lamellibranchs, gastropods, brachiopods and trilobites are frequently seen in the shale, while but traces of such have as yet been observed in the Normanskill shale.

The dark shales contain not infrequently thin, sandy bands and still oftener intercalations of sandy limestones and also gray crystalline limestone, reaching half a foot in thickness. These bands frequently contain a faunule of brachiopods, crinoid joints, etc., and they have furnished the great number of fossils, other than graptolites, recorded by the writer in Bulletin 42. Frequently concretions of both limestone and clay are found scattered or more or less obscurely arranged in layers.

Owing to the extreme pliability of the argillaceous shales and the lack of strengthening intercalations of grits etc., the Snake Hill beds are, as a rule, intricately contorted and crumpled and cut by cleavage planes and smoothed slip planes, until they have the character of the shales which were termed by the geologists of the first survey "glazed" and "semimetamorphic" shales. These shales so designated were Snake Hill shales of the Hudson valley. Yet, localities have been observed, as at the west shore of Saratoga lake, where these shales were distinctly slaty, and near Argyle, just beyond the edge of the sheet, they have been quarried for slate.

At Snake hill — a picturesque high promontory on the east side of Saratoga lake and an old landmark, suspected by many of the settlers of the region of being an "old volcano"— the formation has a different character, the shales containing here compact grit and conglomerate beds 1 to 4 feet thick, consisting of coarse sandstone with silicious and argillaceous cement and many pebbles, up to 1 inch in diameter, well rounded and consisting of shale, black limestone, cherty "white bed" and milky quartz. While the grit and conglomerate beds are bent into recumbent, nearly flat folds, the intercalated shales are intensely crumpled. There also occur thinner beds of gray, crystalline, often sandy limestone. In following the grit beds along the shore it is seen that they are not very extensive, very irregular in thickness and sometimes replaced in a short distance by shale. All the rocks of this locality, the shales, the limestone bands, the grits and the conglomerates, are fossiliferous and besides a few graptolites furnish cystids, crinoids, brachiopods, gastropods, pelecypods and trilobites. In the shore cliffs of the lake a mile north of Snake hill, lamellibranchs and gastropods occur in association with some of the characteristic graptolites of the formation, and in the little disturbed beds of the west shore the graptolites were found in fine preservation in a number of places.

Only one other outcrop of the conglomerate bed was observed, 6 miles northeast of Snake hill. The bed may therefore be lenticular and of but local extent. Intercalations of silicious shales weathering whitish and of sandstone beds were observed in the section exposed along the road leading southeast from Gansevoort to the Hudson river. These were, however, in every case insignificant in thickness and less characteristic in development than those of the Normanskill formation, the thickest sandstone bed measuring but 3 feet.

The Snake hill locality has furnished the following fauna:

Graptolites
- Dicranograptus nicholsoni *Hopkinson*
- Diplograptus (Mesogr.) putillus *Hall*
- Corynoides *sp.*

Crinoidea
- Glyptocrinus *sp.*
- Heterocrinus? gracilis *Hall*
- Cremacrinus *sp.*
- Carabocrinus *cf.* radiatus *Billings*

Cystoidea
- Edrioaster saratogensis *Rued.*

Bryozoa
- Paleschara ulrichi *Rued.*

Brachiopoda
- Schizocrania filosa (*Hall*)
- Plectambonites sericeus typus (*Sowerby*)
- Plectorthis *cf.* whitfieldi (*Winchell*)
- Dalmanella testudinaria (*Dalman*)
- Plaesiomys retrorsa *auct.*
- Rafinesquina alternata (*Emmons*)
- Clitambonites americanus (*Whitfield*)
- Parastrophia hemiplicata *Hall*
- Zygospira recurvirostris (*Hall*)

Pelecypoda
- Whiteavesia cincta *Rued.*
- W. cumingsi *Rued.*
- Orthodesma? subcarinatum *Rued.*
- Whitella elongata *Rued.*
- Clidophorus ventricosus *Rued.*
- C. foerstei *Rued.*
- Ctenodonta levata (*Hall*)
- C. declivis *Rued.*
- C. prosseri *Rued.*
- C. radiata *Rued.*
- C. recta *Rued.*
- C. subcuneata *Rued.*

Lyrodesma schucherti *Rued.*
Solenomya? insperata *Rued.*
Cuneamya acutifrons *Ulrich*

Gastropoda

Archinacella orbiculata (*Hall*)
Cyclonema montrealense *Billings*
C. cushingi *Rued.*
Clathrospira subconica *Hall*
Pterotheca *cf.* canaliculata (*Hall*)

Crustacea

Eoharpes ottawensis *Billings*
Trinucleus concentricus (*Eaton*)
Proëtus undulostriatus (*Hall*)
Calymmene senaria *Conrad*
Lepidocoleus jamesi *H. & W.*
Ctenobolbina subrotunda *Rued.*
Technophorus cancellatus *Rued.*

Other localities which deserve notice are:

1 The shore 1 to 2 miles north of Snake hill, where the shales contain:

Dicranograptus nicholsoni *Hopkinson,* abundant
Diplograptus amplexicaulis *var.* pertenuis *Rued.*
D. (Mesograptus) putillus *Hall*
Archinacella orbiculata (*Hall*)
Leptobolus *sp.*

2 West shore of lake (Edgewater Park, Rileys etc.):

Dicranograptus nicholsoni *Hopkinson*
Glossograptus quadrimucronatus *mut.* pertenuis *Rued.*
Diplograptus amplexicaulis *Hall*
D. amplexicaulis *var.* pertenuis *Rued.*
D. (Mesograptus) putillus *Hall*
Climacograptus spiniferus *Rued.*

3 A thin sandstone band in the shale at the foot of the hills east of Moses kill contains:

Schizocrinus *cf.* nodosus *Hall* (joints)
Dalmanella testudinaria (*Dalman*)
Plectambonites sericeus (*Sowerby*)
Rafinesquina alternata (*Emmons*)
Cyclora *cf.* minuta *Hall*

Spyroceras bilineatum (*Hall*)
Proëtus undulostriatus (*Hall*)

4 A similar faunule was obtained in a thin limestone band, consisting entirely of shells, intercalated in the shale at the bank of the Hudson river, 2 miles above the mouth of the Snook kill. Here were found:

Glyptocrinus *cf.* decadactylus *Hall* (joints)
Corynoides gracilis *Hopkinson*
Lasiograptus eucharis (*Hall*)
Plectambonites sericeus (*Sowerby*)
Dalmanella testudinaria (*Dalman*)
Trinucleus concentricus (*Eaton*)

Thin limestone bands consisting of shells of Dalmanella and crinoid joints were met with in a number of localities.

5 The black shale brought out of the canal at Fort Miller contains:

Diplograptus amplexicaulis *var.* pertenuis *Rued.*
Diplograptus putillus *Rued.*
Lasiograptus eucharis *Hall*
Leptobolus *cf.* insignis *Hall*

Sandy and calcareous bands

Joints of Schizocrinus nodosus *Hall*
Dalmanella testudinaria (*Dalman*)

The outcrop of black shale below the dam in the Batten kill at Crowe's 1¾ of a mile above Clarke's Mills, contains:

Corynoides gracilis *Hopkinson*
Diplograptus (Mesograptus) putillus *Hall var.*
Diplograptus amplexicaulis *Hall*

and the shale below Middle Falls

Corynoides calicularis *Nicholson*
Diplograptus (Mesograptus) puillus *Hall var.*
Worms (*cf.* Pontobdellopsis cometa *Rued.*)

The localities between the Hudson river and Willard mountain and on the other side of the river have afforded:

Diplograptus amplexicaulis *Hall*
Diplograptus (Mesogr.) putillus *Hall*
Lasiograptus eucharis (*Hall*)
and abundant worms (*cf.* Pontobdellopsis)

The fossils which are most frequently met with in the shales are: the graptolites Corynoides gracilis, Dicranograptus nicholsoni, Diplograptus amplexicaulis, D. amplexicaulis var. pertenuis, Climacograptus spiniferus, and the little gastropod Archinacella orbiculata and little lamellibranchs of the genera Clidophorus and Ctenodonta, while the limestone and grit bands contain the brachiopods Dalmanella testudinaria, Plectambonites sericeus, fragments of Rafinesquina and crinoid joints. Rarely a larger fauna of mollusks and trilobites occurs, as at Snake hill, and some places in Albany county. Also worms similar to those described from the Canajoharie shale are frequently seen.

The frequent occurrence of Dicranograptus nicholsoni typus which is not found in the Normanskill shale, appears to us especially characteristic of this formation, especially about Saratoga lake, while Lasiograptus eucharis, which is extremely common in the Canajoharie shale, is here less frequently met with.

Correlation. From the fauna of the Snake Hill beds it can be inferred that the formation is of early Trenton age and roughly corresponds to the lower and perhaps part of the middle Trenton. It probably rests upon the upper division of the Normanskill shale and is the youngest of the rock formations of the Levis basin that by overthrusting and intensive folding have been pushed westward into contact with the formations of the Mohawk-Champlain basin (see diagram, page 140).

STRUCTURAL GEOLOGY OF THE SHALE BELT

BY R. RUEDEMANN

The principal structural feature of the shale belt of the two quadrangles finds its expression in the contrast of the flat-lying or but slightly dipping shales of the western trough and the intensely folded and crumpled condition of all the rocks east of this belt.

The boundary line between the folded and flat shale areas coincides very nearly with that between the Canajoharie and Snake Hill shales, not only on the two quadrangles here described, but in the entire inner lowland extending from the Helderberg cuesta to the Adirondacks and then into the Champlain basin and presumably farther north. It does not coincide exactly because in some regions the folding has transgressed a few miles into the Canajoharie shale area while in others some western marginal cakes of the Snake Hill beds have been left only shattered by fault slips. Thus in Albany county the Canajoharie shale belt striking along the Hudson river has become, partly at least, involved in the folding, while on the Saratoga sheet the Snake Hill shales west of Saratoga lake are only tilted and broken. The boundary between the folded and unfolded areas follows thus on the Schuylerville quadrangle the longer axis of Saratoga lake, being probably in part responsible for the existence of this basin in that place. It thence continues northwest passing west of Kendricks hill where folded Snake Hill shales are exposed. The folded area may also include the last outcrops of Canajoharie shale on the Snook kill below Gansevoort, the shale being there in steeply eastward dipping position.

In general, however, the boundary of the folded and unfolded regions coincides so closely with the Canajoharie-Snake Hill boundary that the proposition of the folding and shoving of the eastern series of shales upon and against the western is well supported by this fact. The crumpling up of a narrow belt of Canajoharie shale in front of the folded area in Albany county on one hand and the shoving westward of a cake of Snake Hill beds without folding (but with much slipping, see below page 103) in Saratoga county on the other hand, both result from the varying resistance offered the oncoming waves of pressure and of folds from the east, through the thickness of the opposing strata and the weight of their covering formations. It appears from the fact that some of the outcrops on the southeast shore of Saratoga lake (on the Cohoes quadrangle) show a great number of closely arranged thrust planes, all rising slightly to the west, that the pushing force in this more or less unfolded western cake was largely spent in overthrusting, this action taking place near the surface under little or no cover.

We have shown before that the Canajoharie and Snake Hill beds belong to different series of rocks, deposited in different basins. Of these the Canajoharie shales have changed their position on the whole only vertically through normal faulting, while the folded shales must have been transported for some distance subhorizontally to come to lie in contact with and partly above the western series. This transportation took place both by folding and overthrust faulting. There is little doubt that the western series has been overridden by the rolling and slipping mass of the eastern shales and grits to an extent at present unknown. We have in the sections extended the Canajoharie shale and the underlying limestones and sandstones to the eastern hill region, because from the thickness of these formations at Saratoga it is sure that they continue for a considerable distance eastward under the crumpled shales. Quite probably they descend gradually eastward under a subhorizontal thrust plane, partly by step faults, such as bring the limestones at Saratoga Springs down to the level of the village (see diagram on left).

The Canajoharie shales of the western belt exhibit but gentle dips in most outcrops. In the region of the Glowegee the dip is to the west toward the fault and to the southwest, while about Saratoga and on the Schuylerville quadrangle it is mostly to the east and southeast, usually less than 5°. Exceptions are the outcrops on the upper Snook kill, at the foot of Mt McGregor, where the dip is on the average 50° and as high as 65°, owing to the nearness of the McGregor fault line that separates the shale and Precambric rocks. At Gansevoort the shale is already much disturbed by slipping and folding, but in general dips steeply southwest, while at Fort Edward, a few miles beyond the limits of the quadrangle, the dip is about 12° to southeast. Both at Gansevoort and Fort Edward a great number of small slips occur, and the varying dip to northwest and southeast indicates that the shale belt is broken into many tilted blocks by faults more or less parallel with the master faults, that is, faults running in southwest-northeast direction. None of these larger faults has been directly observed in the shale. Nevertheless their presence can be directly inferred in several places, as at Rock City Falls and half way between North Wilton and Saratoga Springs, where faults pass from the limestones southwestward into the shales. The fault separating Canajoharie and Snake Hill beds at Ballston may also belong in this class.

Besides these supposed larger faults, a multitude of small slip faults transect the shale. All of these strike northeast, more or less parallel to the master faults, dip slightly to the east and the upthrow side is on the east, all of these faults being of the nature of small overthrusts. The throw is everywhere small, being but a few feet or in some cases only a few inches. Three of them were observed in the lower gorge of the Kayaderosseras, others in the Snook kill near Gansevoort. The best instances of these small overthrusts in the Canajoharie shale occur at the dam at Fort Edward. Here the shale is already somewhat contorted and folds that are inverted to the northwest are exposed. The entire mass of rock is, however, cut by a great number of slip or overthrust faults, dipping southeast at 12° to 14°. The throw is always very small and the thicker and harder beds in the shale are seen to be broken by the slip planes, the upper part being thrust forward a little over the lower, the whole suggesting surface thrusts. These small slips and folds in the eastern margin of the flat shales of the western basin were produced either below the overriding eastern rock masses or in front of them. The step faults prevail therefore in the western part of the belt and the slip faults in the eastern.

At Hudson Falls, a few miles north of the Schuylerville quadrangle, the Canajoharie shale, in being pushed northwestward before the eastern rock masses, appears to have encountered some resistant body which twisted the shales; they are here shattered and filled with a great profusion of calcite veins. It seems as if the spur of limestones and dolomites that protrudes through the shales a mile farther west, at Glens Falls, had been this resistant boss.

Folded area. The structure of the folded area is of the most complex character imaginable. It will be discussed in two parts, (1) the structure of the Ordovicic shale in the Hudson River plain, (2) the structure of the Georgian rocks and associated Ordovicic formations in the eastern (Greenwich) hill region.

The shale belt of the Hudson River plain in the folded area consists principally of the Normanskill shale in the middle and the Snake Hill shale on both sides. This entire mass is uniformly thrown into a mass of closely packed, small closed folds that are asymmetric and uniformly overturned or inverted to the west, so that on the surface and in sections where the tops of the anticlines are eroded away, the entire mass has an isoclinal structure, all beds dipping to the east with varying angles, averaging about 70°. This is especially true where only shales are involved. Where, however, more resistant beds, especially the grit beds, are present, these appear to be folded into less compact or closed folds, and they are liable to form broad open folds in one place and recumbent ones in places near by, as on Snake hill. In the Rocky tucks each leg of the inverted anticline forms, as a rule, a ridge by itself, the roof or top of the anticline being broken out. These small anticlines are mostly of short length, pitching often considerably at the north and south ends. They cause the grit and chert ridges to rise for a short distance above the surface to soon disappear again.

It is probable that also in the Saratoga plain in places a number of smaller anticlines and synclines are combined into larger anticlinoria and synclinoria. At least the presence of a multitude of small grit anticlines in an elliptic space, as in the Rocky tucks, would suggest the probability of such a more complex structure. There is little doubt that anticlinoria and synclinoria exist farther east,[1] where the pushing force was greater and the rocks more resistant, but in this western shale belt the entire crumpled, minutely and often irregularly folded mass has the appearance of a rolling and slipping mass, not strong enough to be thrown into folds of mountain-making magnitude. Yet we find already close to the east, in the hill region, as in Willard mountain, clear evidence of a syncline on such a larger scale.

These folded and crumpled shales are further cut by a very regular cleavage and by faults. The cleavage is ever present in the folded shale region; the cleavage plane dips nearly always to the east, similar to the bedding planes, most frequently intersecting the latter at an acute angle.

While the contorted appearance of the shales in consequence of the many folds often gives the whole mass the appearance of having yielded to the pushing force by simply crumpling up, there is also everywhere evidence of a slipping of the rocks along innumerable slip planes or small thrust faults. We have already mentioned their presence in the eastern portion of the little disturbed Canajoharie shales. In the folded area, however, we have met them everywhere. In the good east-west section, for instance, which the Batten kill furnishes at Clark Mills, a whole series of such faults, about 10 to 20 feet distant from each other, were observed in the north wall and traced across the river bed. They all rise toward the west at angles varying from 20° to 45° and many are made conspicuous by calcite veins. The throw is always small, but the upthrow side is always pushed a little to the west. On the west shore of Saratoga lake where the shale lies in places nearly flat, one overthrust plane was observed that was nearly horizontal; in the cliffs of the southwest shore of the

[1] Dale p. e. has described Mt Greylock as a synclinorium.

same lake (on the Schenectady quadrangle) many such overthrust faults were observed; in one place three above each other. They all dip southeast, mostly at an angle of about 25°. Others were observed in the bed of Fish creek at Victory Mills and in road metal pits. In one place, a road metal pit east of Saratoga lake, the slickensides upon the thrust planes, and especially the direction of the slickenside scales, left no doubt that the upthrow side had moved from east to west upon that plane. Some of these overthrust faults have clearly resulted from overturned folds (fold thrusts). The upper leg is seen in such cases to have been pushed westward beyond the lower. Some instructive examples of this were seen about Saratoga lake, especially on Snake hill. Most of these small faults run with the general strike (north-northeast direction) of the beds or are strike faults; some were, however, observed which cut the beds obliquely, as one at Victory Mills, striking N. 60° E. These deviations from the general north-northeast direction are probably connected with local irregularities in the general trend of the folds.

While the throw of each of these overthrust faults is but small, their accumulative effect, going from west to east, owing to their great number and uniform direction of throw, must be quite large. If we assume a throw of 6 inches for each fault and that they are 20 feet apart, we obtain for the belt measured from the foot of Willard mountain normal to the strike, with a width of 10 miles, a compound throw of 1320 feet. The effect of this accumulative throw would be to bring progressively older beds to the surface of the Saratoga plain as one goes east. It is therefore possible that the position of the Normanskill belts to the east of the Snake Hill belts is largely due to this effect of the small numerous overthrust faults which might be termed "*progressive overthrusts.*"

The interesting observations of Woodworth[1] have shown that faulting of "repetitive" character is still going on in the shale belts to the south of the Schuylerville quadrangle and possibly also in the latter. These small faults have also the same northeast strike and where observed, raise the eastern part above the west-

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[1] Woodworth, J. B. Postglacial Faults of Eastern New York. N. Y. State Mus. Bul. 107, p. 5, 1907.

ern, and may therefore be a continuation to the present day of the "progressive overthrusting" here described.[1]

There is, however, also evidence of possible larger faults, both normal and overthrust, in the folded shales of the Saratoga plain. One larger fault is directly observable at Ballston Spa, separating the Canajoharie shale and Snake Hill beds. This fault is traceable southward through the Ballston lake depression toward the Mohawk river. Its presence is shown by the steep eastward dip of the Snake Hill beds, which rapidly decreases as one goes east, the part of the Snake Hill belt between Ballston Spa and the lake being but little disturbed by crumpling. From present evidence we infer that an important thrust plane separates the Snake Hill and associated now intensely crumpled formations of the eastern basin from the relatively undisturbed Canajoharie shales, along this fault line northeastward beyond the limits of the map. This fault, which is probably a nearly horizontal thrust fault (see diagram), is of the character of a "scission" fault or "charriage." The eastern formations have been pushed westward over this plane for an unknown, but probably considerable, distance. If our conclusion that the Rysedorph Hill conglomerate properly comes in the upper part of the Normanskill shale is correct, then its absence near the boundary line of the two on the Schuylerville quadrangle would also indicate that this line is not one of normal stratigraphic succession, but of diastrophism or movement of the earth crust. As we have shown above, the entire shale belt is transected by a great number of slips or thrusts of small throw, which combined might be competent to bring up the older shales in overlying position to the younger ones; they would, however, not throw the Rysedorph Hill conglomerate out of its supposed normal position near the top of the Normanskill beds.

Whatever the character of the contact along the western edges of the Normanskill areas may be, it seems clear that it is in the nature of an overthrust, either a single large overthrust or a

[1] Woodworth (op. cit. p. 26) is inclined to explain these small faults as step faults with a downthrow to the northwest, which would produce the same effect as an overthrust from the east, and to consider them as part of a tilting of the land in and about the New England district, since the retreat of the Wisconsin sheet, or as resulting from the lifting out of the cores of synclines through lateral pressure from the east. Since the synclines, as a rule, are overturned to the west and compressed into close folds in the shale district, it is improbable that the forcing out of the core of the synclines could be responsible for the numerous small overthrusts observed by us.

number of small ones of the character of progressive overthrusts. In the western Normanskill area this is suggested by the pinching out of the grit belt, as stated before, against the western boundary of the area. The line bounding the Willard mountain area of Normanskill rocks on the west is to all appearances of the same character, for this would explain in part that the older Normanskill rocks project here more than 1000 feet above the younger Snake Hill beds adjoining them to the west, and that we find structures, as the cross fold in the southeast corner of the sheet, cut off by that line.

If the eastern Normanskill belt is also overthrust westward, it would seem to have been not only overthrust, but also thrown into the high mountain folds of Willard mountain before the oncoming of the Georgian overthrust waves, for the latter were clearly turned aside by this projecting mass, as shown by the curving strike of the Georgian rocks northeast of Willard mountain. That it still in this late time projects so boldly is of course mainly due to the great hardness of the grit and especially of the white-weathering chert beds which form its backbone.

As far as this relatively small area indicates, we have here a series of successive overthrust masses, producing the intricate structure which in various parts of Europe is known as "Schuppenstruktur," the separate Schuppen being pushed over each other like scales (Schuppen).

While the prevailing material of the rocks that have been overthrusted consists of shales, there are, it appears to us, sufficient masses of solid, hard grit and chert beds in the Normanskill and Snake Hill shales and of limestone and quartzite beds in the Georgian rocks to have transmitted the stress to the shales. Also the compact Bald Mountain limestone and dolomite must have been important agents in the development of the overthrusts. In the Bald mountain section (see page 109 and sections and diagrams in pocket) the limestone is seen to be bounded by overthrust planes from the shales above and below, showing that the shear followed in some places the bedding planes between the limestone and shale, thus separating the two. It is possible that the successive overthrusting took place similarly as suggested by Bailey Willis[1] for the Alpine structure, although we have been led to infer from our observa-

[1] Bailey Willis. Thrusts and Recumbent Folds, a Suggestion Bearing on Alpine Structure. Science, 25:1010.

tions that the uppermost thrust plane, that of the Georgian, is the youngest, while Mr Willis considers the lowest, the great major thrust C of his diagram as the youngest.

The appearance of a narrow belt of Schaghticoke shale between Schuylerville and Thomson is evidence of a fault in that section, for since the Schaghticoke is separated by the considerable thickness of Deep Kill shales from the Normanskill shale and these are absent at Schuylerville,[1] a single anticline would not explain the occurrence. It is either a mass, entirely separated from its roots in the contorted and crumpled shale mass, or a small fault block thrust through the other shales. Close by is the " Northumberland volcanic plug," which also is cut by slickensided planes striking in the general direction of the faults of the area; and which, according to Professor Cushing's investigations, may be a similar small block, torn off its main mass and carried forward with the shale masses of the " Decke."[2]

The structure of the Greenwich plateau. The Greenwich plateau enters the Schuylerville quadrangle from the east with a belt only 1 to 2 miles wide. We have to distinguish two structures in the part of the plateau with which we are concerned, namely, the Willard Mountain syncline and the Georgian overthrust mass.

1 *Willard Mountain syncline.* We have mentioned above that the imposing and historic Willard mountain, which rises boldly more than 1200 feet above the bed of the Hudson river, presents the structure of a syncline, much larger and more open than the synclines observed in the shales of the Saratoga plain. This open structure is obviously due to the presence of a great amount of grit and silicious, cherty shale in the strata folded there. At the northeast end the strike of the beds swings around from northeast to northwest, suggesting that the syncline terminates here abruptly with a well-rounded curve. At the eastern foot of the mountain a coarse conglomerate forms the crest of a small anticline.

2 *Georgian overthrust blanket.* If one wanders from the Hudson river, for instance at Thomson or Clark Mills eastward,

[1] We omit here the distant possibility that the Beekmantown beds could be absent in the series at Schuylerville, although it has been claimed that they are intermittent.

[2] Since " blanket " corresponds to the German " Decke " and means *a cover,* relatively thin, such as these thrust masses are, they might be called " thrust blankets." The word " sheet " would be liable to confusion. The French " carriage " is also transferable, although the meaning of the English word carriage for " that which is carried " has become archaic (Webster).

one passes in the Hudson River plain over Snake Hill shales, frequently covered by quaternary clays, until near the foot of the hills marking the edge of the Greenwich plateau. Here there is a belt of much broken and distorted Beekmantown limestone (Bald Mountain limestone) and coarse conglomerate (Rysedorph Hill conglomerate), and the hills themselves and the plateau behind them consist of the Georgian rocks. The latter, although immensely older, hold a higher level than the shales west of them. The explanation of this remarkable fact is that the Georgian has been overthrust upon the Ordovicic rocks. This is most clearly shown at Bald mountain where the former quarrying of the limestone at the foot of the mountain has opened a splendid section (see plate of sections).

Bald mountain is, geologically speaking, an historical mountain. It has played a conspicuous rôle in the Taconic controversy and it is therefore proper in this place briefly to review its history. Emmons was the first to direct attention to the Bald Mountain section as being an interesting example in the relative position of the "Taconic" and "Champlainic" (Ordovicic) rocks, that is, as showing the Champlainic rocks as resting unconformably on the Taconic rocks. He gave (1846, page 89) a section through Bald mountain showing the "calciferous sandstone" extending from the top of the mountain to the western foot where it is underlain by the "Taconic" black slates, which also appear on the eastern foot of the mountain. The two trilobites Atops trilineatus and Elliptocephala asaphoides, which demonstrated the actual presence of rocks older than Potsdam in the slate belt, were also cited as coming from the strata "near Bald mountain"[1] (*op. cit.,* page 63).

Walcott (*op. cit.,* page 317) has shown that the complex structural relations of Bald mountain are entirely different from what Emmons supposed them to be. He found Georgian fossils in the limestones, forming the summit of the mountain, and states: "Doctor Emmons identified this mass of strata, *d,* with the calciferous sandrock on lithologic characters, overlooking the fact that a similar rock might occur in his Taconic series." Walcott also recognized the overthrust at Bald mountain. He says: "The section of Bald mountain proves that the strata of the 'Upper

[1] Walcott (*op. cit.,* p. 326) cites them as coming from the black slate 2 miles north of Bald mountain, where Doctor Fitch found them.

Taconic' are there pushed over on to the Chazy Terrane, and that the 'Upper Taconic' is not unconformably subjacent to the latter or to the Calciferous sandrock."

The fossiliferous limestone of the downthrow block is Beekmantown; the lower, darker dolomitic beds belong to the same formation with the upper, lighter, purer limestones, being separated at Bald mountain by an inthrust wedge of shale and conglomerate. The black slates which Emmons considered as the Taconic black slates underlying the "calciferous sandrock" are the Snake Hill shales, and his conception of the structure of Bald mountain has thus become completely reversed.

The Bald mountain section is of great interest, not only in regard to the Taconic controversy and the different explanations offered for it, but especially as distinctly showing an overthrust of the Georgian rocks upon the Ordovicic beds and the thrust-shattered condition of all the beds involved in the section. The photographs on plates 12–14 show the limestones much broken by thrust planes auxiliary to the master overthrust, and overlain by masses of mylonite (see page 84) upon which rest the Georgian shale and shaly limestone. There remain standing detached cliffs or blocks consisting of conglomerate and shale on the south side and in front of the quarry, which indicate the former extent of this formation, while to the southwest and west of the quarry there outcrop in several places the dark dolomites (see diagram of front of mountain, plate of sections). It thus appears as if the shales and conglomerates separate the pure limestone above and the dark dolomite below. As we have stated in another place, these two divisions both north and south of Bald mountain grade into each other and form one formation. It is therefore probable that the shales and conglomerate in front of Bald mountain form only a wedge thrust in between the limestones and dolomite.

Dale (*op. cit.*, page 293), from his elaborate investigation of the New York-Vermont slate belt, arrived at the conclusion that the overthrusting at the western margin of the Cambric area is only local in the shale region of New York-Vermont. He says:

The striking features in all these localities, leaving out the last, are the uniformity of the dip, the great thickness of the Lower Cambrian, and the thrusting over of the latter on the Trenton. These features imply great rigidity in the beds and relief of compression through faulting. These, however, are just the features which are wanting along the slate belt. The

Cambrian beds are all in minor folds, as are certainly the several isolated Ordovician areas and the large central ramifying ones. And there is no evidence of such a great overthrust as at Burlington and Saint Albans. But Mr Walcott does find evidence of an overthrust on Bald mountain, in the town of Greenwich, in Washington county, New York, west of the slate belt. The exposures described near North Granville (page 292) also indicate reverse faulting. Yet the course of the Cambro-Ordovician boundary along the western edge of the slate belt, particularly northeast and southwest of North Granville, New York, and in Benson and Hubbardton, Vermont, and again in the townships of Hartford, Argyle, and Hebron, New York, is hardly consistent with the existence there of a great longitudinal overthrust, nor do the vertical relations of the Ordovician and Cambrian outcrops favor such a construction. If such a thrust plane separates the two formations, it must be a folded thrust plane, which is not an ordinary probability.

It would appear, therefore, that the great mid-Silurian orogenic movement which, in northern Vermont, operating upon rigid beds, found relief in a great overthrust, at the south, near the slate belt, operating upon beds which were more plastic, compressed them into minute folds. In either case the compression at the south found relief chiefly in folding, and only here and there, as about North Granville and at Bald mountain, in faulting. But evidences of faulting may be found west of the area here mapped.

In 1901 (page 555ff.) the writer explained the inverted order of the formations observed by him in the neighborhood of Albany by an overturned fold which changed into an overthrust fault, whereby the Georgian became overthrust upon the underturned wing. This view was also reached by Dale in the Geology of the Hudson Valley between the Hoosic and the Kinderhook (1904, page 38). He states: "That the relations on the west side of the Cambrian belt are not only those of unconformable deposition but of more or less continuous overthrust is rendered somewhat probable from the situation of the overthrust near Schodack Landing and of that at Bald mountain in Greenwich, 47 miles north-northeast of the former, as well as from the general direction of the Cambro-Hudson boundary between them. . . . For these reasons it is assumed that in consequence of a westwardly overturned fold, which is frequently ruptured, the Lower Cambrian here usually overlies the Hudson, that is, the Trenton or middle part of the Ordovician."

The subsequent work of the writer seems to indicate that this view as to the origin of the overthrust of the western margin in which he and Dale agree, is the one nearest the truth. We see possible evidence of this hypothesis in the belt of Bald Mountain limestone of Beekmantown age, outcropping below the Georgian along the western edge of the Greenwich plateau. This limestone, which, on account of its Beekmantown age, now recognized, is to be considered as underlying the Snake Hill shale, just below it, may indicate an inverted order below the Georgian, although there is a stronger probability that its presence is due to its having been brought along with the Georgian along the trust plane.

Our observations along the west edge of the Cambric area, not only on the Schuylerville quadrangle but also northward and south of it in Rensselaer and Columbia counties, have led us to the conclusion that we have there precisely that case which Dale considered as not an ordinary probability, and therefore would exclude from his working hypotheses, namely, a folded thrust plane, along which the Georgian rocks have everywhere been overthrust over the Ordovicic rocks. This condition is, in our opinion, a structural feature of the first magnitude of the entire plateau. Likewise the underlying Ordovicic is not only compressed into small folds from the east, but also more or less bodily overthrust over the series of rocks of the Western basin. The same intense pressure which only a few miles farther east caused the regional metamorphism of all these shales, has to be considered as competent to produce the folding and the extensive overthrust faulting.

The facts which induce us to consider the entire western part of the Cambric area at least as overthrust on the Ordovicic rocks, are of both structural and topographic nature. The strike of the Ordovicic rocks in the Saratoga plain leads these rocks directly under the Cambric rocks of the Greenwich plateau, as a glance on the Schuylerville map will show. While from the northeast corner to the foot of Louse hill the Snake Hill beds pass under the Georgian rocks, in the southeast corner of the quadrangle, north and east of Willard mountain, the Normanskill rocks disappear under the Georgian rocks. In several localities where rivers have breached the margin of the Cambric Greenwich plateau, the Ordovicic rocks can be traced upward along the river, forming reentrant angles in the outline of the Cambric. Such a large reentrant or embayment is formed by Moses kill and another broader one by the Batten kill.

Very instructive are the cases of the Hoosic river and Deep kill. At Schaghticoke the Schaghticoke shale (of lowest Ordovicic age) is exposed in the bottom of the river, while the hills to the north and south of the gorge, in the general strike direction of the rocks, consist of Georgian rocks. Likewise at Grant hollow, where the writer found the Deep Kill graptolite fauna in the bottom of the gorge, the tops of the hills on both sides of the gorge are fossiliferous Georgian. The latter occurrence is of great interest because it connects the Ordovicic shale belt, west of the overthrust line, with the large Mt Rafinesque-Rice Mountain "Outlier." If the Georgian rocks overlie the Beekmantown graptolite shale at Grant hollow, it can be inferred that this outlier is really a "Fenster," or a portion of the Ordovicic rocks underlying here the Georgian mass, but exposed by erosion.

There is considerable and quite conclusive evidence that the thrust plane is irregular in its hade, through folding; for while the thrust plane is very slightly inclined at Bald mountain and the Moses kill, it is steep east of Willard mountain, and in the neighborhood of Troy. That these differences are due to folding of a character transversal to the general northeast strike of the beds is indicated by the fact that where the hade is steep, the Georgian rocks descend deeper than where it is flat, as in the valley of the Batten kill, these regions corresponding to depressions or synclines.

There is considerable evidence extant of folding of the entire region long after the Green Mountain revolution, marking the Ordovicic-Siluric boundary, and which is considered responsible for the principal folding and overthrusting of this region. Such later folding is shown by the folded condition of the Rensselaer grit, that is probably of Upper Devonic age, and the remnants of the folded and overthrust Devonic limestones still found along the Hudson river. We have here especially in mind the Kingston region, the folded and overthrust structure of which has been so well worked out by Van Ingen and Clark.[1] These authors have shown there the presence of a practically horizontal overthrust plane, the thrust of which comes from the east and which is possibly a manifestation of the same force that pushed the Georgian rocks over the Ordovicic rocks on the other side of the Hudson.

The question whether the overthrust at the western edge of the Cambric area recognized by both Doctor Dale and the writer, reaches so far back east that the large Georgian area is all over-

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[1] Gilbert van Ingen and P. Edwin Clark. Disturbed Fossiliferous Rocks in the Vicinity of Rondout, N. Y. N. Y. State Mus. Bul. 69, p. 1176. 1903.

thrust upon Ordovicic rocks as an extensive "carriage," is one that is exceedingly difficult of solution on account of the intensely folded condition of all the rocks involved and this condition is the cause of differences of opinion. We differ from Dale in the eastward extension which in our view this overthrust faulting has attained. We have already above presented evidence that some of the "outliers" of Ordovicic rocks on the Cambric plateau are not such simple outliers, as claimed by Dale, but "Fenster" (windows), that is, portions of the underlying but younger Ordovicic rocks exposed by erosion, and the very small outlier of Ordovicic at Sudbury, under which Dale[1] found Georgian rocks can not be considered as vitiating the other evidence on account of its small size (but 50 square meters) and nearness to a larger Ordovicic body, which suggests that it may be but the remnant of a small infolded mass, such as are apt to occur near the Georgian-Ordovicic boundary on account of the contorted condition of the rocks. Those "Fenster," which we have in view, as especially that connected with the Ordovicic shale belt of the Hudson River plain by the Deep kill gorge (see page 112) lie close to the western edge of the Georgian area, and indicate an overthrust plane as far east as they extend. We see strong evidence for the far eastward extension of the overthrust in the appearance along the western edge of the Georgian area of such rocks as the Bald Mountain limestone, which are totally different from the rocks of the northern trough, and also lacking in the broad belts of shales of the Western trough to the north and south, and which therefore must have been brought a considerable distance from the east, if we will not assume that the limestone was again eroded over most of the area before or during the deposition of the Normanskill shale, an assumption that seems supported by the Rysedorph Hill conglomerate.

The evidence which has been gathered by us in this relatively small area, regarding the overthrust condition of the rocks, is in full accord, as far as it goes, with the views expressed by Ulrich in the Revision of the Paleozoic System, page 442, on the overthrust troughs in eastern New York and western New England.

[1] T. Nelson Dale. The Ordovician Outlier at Hyde Manor in Sudbury, Vt. Am. Jour. Sci., 33:97. 1912.

Doctor Ulrich distinguishes five different Eopaleozoic troughs, going east from the Adirondacks, first, the Chazy basin, then the Levis channel, a third trough which contains the marble formation in western Vermont and succeeding limestone and shale formations, and possibly the Lower Cambric (Georgian) deposits. The fourth trough is supposed to have contained the Lower Cambric deposits, and a fifth trough, or rather set of troughs, is thought to be indicated by the highly metamorphosed Paleozoics found to the east of the Lower Cambric outcrops. The evidence on which Ulrich bases his belief in the existence of these troughs is threefold: (1) the differences in fossil contents of the sets of beds; (2) the peculiarities in the succession of the various general types of sediments; and (3) the physical proof of excessive folding and overthrusting.

We have in the two sheets here described undisputable evidence of at least two parallel troughs in the two entirely different sets of formations described above. These are the lower Mohawk trough in the west and the Levis trough in the east. If the Georgian and Bald mountain rocks belong to the third or fourth trough, this is also represented on the map. We have here considered them as underlying the rocks of the Levis trough, as they probably do, at St Albans and Georgia in Vermont (see Ulrich, *op. cit.*, page 493). It can not be doubted that the present position of the Georgian beds on the Schuylerville sheet above the graptolite beds of the Levis channel, and again the position of the latter above the beds of the Western basin require for the explanation of this complicated reversed position under the assumption that they represent but two troughs, a reversed anticlinorium with axial overthrust, as assumed by the writer in a former publication (Bulletin 42), or a complicated system of overthrusts and that the assumption of the original deposition of the Georgian beds in a third trough, which now has become pushed upon the second, will considerably simplify the history of diastrophic processes which have led to the present structure of the region.

The cause of these far-reaching overthrust phenomena which are observed in the whole Appalachian system is the pressure attributed to deep-seated " suboceanic spread " which results from the greater density of the terrestrial crust under the oceanic basins, and which is the cause of the Appalachian and Green Mountain-Taconic fold systems but which also, as Ulrich lucidly shows, causes contraction of these tracts of the eastern continental coast by overthrusting, where deep-seated buttresses, as the Adirondacks are opposed to the folds.

One of the overthrust planes which have been observed on the Schuylerville sheet, namely, that separating the Georgian rocks from the underlying Ordovicic beds, can be traced southward along the western edge of the Georgian to a locality near Schodack Landing, about 15 miles south of Albany, where the Georgian belt terminates near the Hudson. It is now an interesting fact that in the direct southwestward continuation of the overthrust plane similar overthrusts can be observed along which the Siluric and Devonic rocks have been moved westward. Chadwick has described such a fault from Saugerties,[1] about 30 miles southwest from Schodack Landing and between the latter place and the large overthrusts at Rondout, described by van Ingen and Clark. If these overthrusts all belong to the same orogenic movement, the latter is at least of post-Devonic age and probably dates, like all the typical Appalachian orogenic movements, from the close of the Paleozoic era, or is still younger.

THE NORTHUMBERLAND VOLCANIC PLUG

BY H. P. CUSHING

One mile north of the village of Schuylerville, near the Hudson river, is a knob of volcanic or effusive rock of quite exceptional occurrence. Woodworth was the first geologist to recognize its true nature and to describe it.[2] Since 1901, when his study was made, a considerable part of the knob has been quarried away for road metal and other purposes, exposing many features of the occurrence which were not originally visible, and also furnishing comparatively fresh rock for chemical study. The reader can obtain some conception of the differences between the knob as seen in 1901 and as it was ten years later by comparing plates 17 and 18.

Woodworth proposed the name of Stark's knob for this hill. The name is a convenient one, and will be here used in referring to it. Since the appearance of his report, Schuylerville people speak of it as " The volcano."

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[1] G. H. Chadwick. Downward Overthust Fault at Saugerties, N. Y. N. Y. State Mus. Bul. 140, p. 157.

[2] N. Y. State Geol. 21st Rept, 1901, p. r17–24.

This occurrence of volcanic rock merits detailed description, both because it is unique and because it is puzzling. It is unlike any other known occurrence of igneous rock in the State or in the neighboring states.

Woodworth's original description of the knob is so excellent that we can not do better than to quote freely from it:

The right bank of the Hudson river here consists of the usual bluff of Hudson River slates partly masked by Pleistocene clays. The igneous rock, being more resistant to erosion than the fragile slates, has withstood better the glacial erosion to which the region has been subjected and therefore stands out as a sort of buttress from the main wall of the inner Hudson valley or gorge. Much like the volcanic necks and plugs about Edinburgh in Scotland, this hard mass has been deeply scoured at base on the ice-struck side. In fact, all of the present relief of this plug and the adjacent river valley is due to the action of the river combined with that of the ice sheet of the glacial period.

The summit of the knob scarcely attains the level of the upland which lies west of the river. A slight depression west of the plug serves to give it the appearance of a low knob when viewed from the upland, but at a distance it is relatively inconspicuous. This fact, taken in connection with the dark color of the rock in which respect it closely resembles the adjacent Hudson series, perhaps accounts for its going so long unnoticed or at least undescribed by the geologists who have passed through the upper Hudson valley. There is no mention of the knob by Peter Kalm or later observers; yet it appears from Brandon's historical map of Old Saratoga that General Stark of the American army occupied the eastern base of this knob during the Battle of Saratoga.

Stark's knob igneous mass lies surrounded on the ground by the Hudson River (Normanskill) slates. These are highly inclined, cleaved, and much broken rocks with a general northeast strike. So far as my own observations go, there are no small dikes radiating from the main igneous mass into the adjacent cleaved sedimentary rocks, nor are there any noticeable signs of metamorphism in these rocks attributable to the heating action of the lavas in the plug. The Hudson river group throughout this region is somewhat altered, but not more so at Stark's knob than remote from it. . . . This lack of contact metamorphism, unless such alteration be limited to baking, which was not observed in the accessible portion of the contact, and the failure of apophyses or branching dikes, are points of little value in determining the origin of the igneous rock in the knob. It remains to determine by other evidences whether the rock is intrusive or extrusive.

On the southeast side of the igneous mass and dissecting its border are two faults; that on the eastern side strikes n. 9° e., that on the southeast, n. 54° e. The southeastern fault is downthrown on the northwest, as on this side there is to be seen the slate underlying a mass of trap on the southeast of the fault. The complete relations of the igneous to the sedimentary rocks on this side are not shown. Figure 9, which is a diagrammatic representation of the cross section of the knob and its peculiar internal structure, shows

Plate 17

H. C. Magnus, photo 1901

Volcanic plug, Schuylerville, Saratoga county. View from the east showing relief of the knob and accessibility of the rock for road metal.

Plate 18

H. P. Cushing, photo

Stark's knob in 1910 from the southeast. Removal of rock has chiefly been from the south end; on the north it has been stripped though but little has been removed. The arrow points toward the slickensided surfaces and shows the position of the camera for plate 19.

this fault, but the figure is purposely drawn with some vagueness on the extreme left of the igneous rock.

To sum up the geologic relations of the Stark's knob igneous mass, it is surrounded on all sides by the Hudson river slates. The principal mass is relatively faulted down into these sedimentary rocks on the south and east. To the eye there appears no distinct evidence of contact metamorphism; yet the mass appears to be the superficial portion of a body which extends downward into the slates and, from its general form and surroundings, strongly suggests a neck or plug rising up through the Hudson river group at this point. The manner in which the slate body dips beneath the igneous mass on the northeast, expressed in figure 9, appears to indicate that the neck or plug does not extend vertically downward through the slates but follows guiding planes of structure. It is conceivable that the igneous rock once overlay the surface of the slates, has been tilted with them in one of the orogenic movements of the region, and has subsequently been faulted

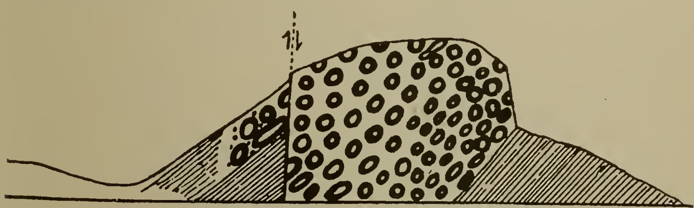

Fig. 9 Cross section of Stark's knob, showing general relation to the slates, and the gross ball structure of the mass

and thus separated from other masses of igneous rock which are now removed by erosion; but this view is not borne out by the observed geologic relations as now exposed.

Structure of the Stark's knob rock. The rock of which Stark's knob is composed is complex in structure. The exposed faces exhibit cross sections of ball and pear-shaped masses embedded in a base having a shaly structure. The crust of these balls consists of a layer of a dense, dark colored basic rock of the diabase type, surrounding a variable nucleus of ashy, rather porous, pumiceous-looking lava in most cases, and more rarely an included marginally absorbed fragment of white, semicrystalline limestone.

The line of demarcation between these three elements in the rock structure is usually very sharp and, where the shaly, fine grained base has peeled away from the surface of the lava balls, the surface of the latter resembles the coarse, bulging flowage surface of basalt streams, such as are seen in Hawaii. The whole has the appearance of a mass of bombs or lava balls inclosing scoriaceous lava, or foreign inclusions embedded in a basaltic glass which has devitrified and is scaling to pieces along lines of flowage. A more probable explanation of the structure is that this mass represents a volcanic throat or plug at some depth below the actual vent or crater but not below the point to which explosive products may have fallen back in the volcano there to become embedded in still hot lava. Certainly the gross structure of the rock recalls many lava sheets with locally formed explosive products, and the same structure is to be observed in the lava flows of the Newark formation of Triassic age in the Connecticut valley[1] (figure 10). The accompanying photograph, plate 17 of the walls of Stark's knob shows the general structure.

The fragment shown in figure 9, lying south of the fault, is more massive than the main stock, and the ground mass approaches more nearly the dense, dark basalt, but here are also developed amygdules.

A hand specimen obtained here displayed fairly coarse crystals of plagioclase, indicative of an intratelluric origin, such as are common in the diabase of many dikes. This combination of the characteristics of dike rocks and of effusive explosive products makes Stark's knob one of the most interesting igneous occurrences, small as it is, within the limits of the State.

Jointing of the lava crusts. The surfaces of the lava balls are beset with a network of cracks perpendicular to the surface. On exposed walls the lava crusts frequently fall to pieces in short, polygonal joint columns similar to basaltic columns.

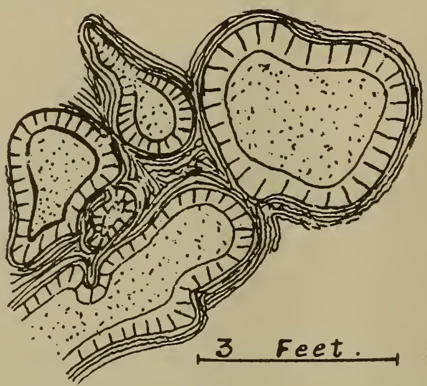

Fig. 10. Sketch of a portion of the western wall of Stark's Knob, showing the gray, scoriaceous interior of the lava balls, the basaltic, jointed crust, and the fissile, devitrified, volcanic glass surrounding the lava balls

The inclusions of limestone point to an irruption through the lower Paleozoic limestones which must occur in this field beneath the Hudson terrane. The inclusions may be appealed to as evidence that the trap came up through the Silurian and subjacent terrane, as held in this paper, and that the rock is not to be regarded as an in-faulted remnant of a lava flow once covering the Hudson terrane in this vicinity.

Since Woodworth's study of the knob, the rock has been utilized for various purposes and largely quarried away. We visited it in 1910, in 1911 and in 1912. In 1910 active quarrying was in progress; in 1911 this was not the case but much material had

[1]Emerson, B. K. Diabase Pitchstone and Mud Enclosures of the Triassic Trap of New England. Geol. Soc. Am. Bul. 1897. 8:59–96. For an illustration of the ball structure at Meriden, Conn., see Davis, W. M., The Lost Volcanoes of Connecticut. Pop. Sci. Mo. 1891, p. 221, fig. 1; U. S. Geol. Sur. 18th Rep't. 1898. pt 2, p. 65.

been removed since our previous visit; between this and 1912 yet more was removed, until now comparatively little of the volcanic rock remains above ground. In addition to our own study of the occurrence we have had the advantage of visiting it with other geologists, with Van Ingen and with Smyth in 1910, with Kemp in 1911 and with Woodworth in 1912.

The result of opening up the knob has been to bring to light certain structural features that Woodworth could not possibly have observed in 1901, and to furnish fresher material for microscopic and chemical study than was available to him. Other features showed better on the old, weathered surface of the rock than in the fresher interior.

Constitution of the knob. The knob consists of lava balls, large and small, with intervening material. The balls range up to 2 feet in diameter. At the time of our first visit many of them lay about, being broken up by the quarrymen. In these we were unable to verify Woodworth's observation that they consisted of a dense exterior and more porous nucleus, though these two layers appeared plainly on the weathered surfaces which he saw. A probable reason for this may be that in quarrying, this exterior crust comes away with the intervening matter, leaving the balls free from it. The deforming agencies which have acted upon the knob may well have had this result. The balls, as we saw them, always had slickensided exteriors, and consisted throughout of similar material. Judging from all the data, it seems probable to us that the balls had originally a glassy crust and finely crystalline interior, and that shearing has separated the crust and nucleus so that they do not come away together in quarrying. For the most part the balls consist of dense, black rock, so finely crystalline that crystals are neither visible to the eye nor to the lens. Exteriorly the balls are occasionally amygdaloidal, but there is no great quantity having such texture.

The intervening material has been badly sheared and crushed, so that much of it has the appearance of slickensided, shaly matter. But some of it is less damaged, especially in the vicinity of limestone inclusions, which seem to have acted to prevent crushing; and here the rock is always of glassy texture, a black pitchstone. This is also sometimes amygdaloidal; and this amygdaloidal glass differs so greatly in appearance from the other amygdaloid, that we took it in the field for variolite. This, however, it does not seem to be.

The cracks which ramify everywhere through the lava are, for the most part, solidly filled with secondary calcite. The amygdules are chiefly of this mineral also.

Woodworth described coarser grained rock, containing feldspar crystals visible to the eye, from the south end of the knob, and the correctness of the description was verified by Cushing's study of the thin section. But we have been unable to find any rock of this type in our later work. Some rock has been removed from the south end though the original thickness was but slight. None of this coarser material remains and we are left in entire uncertainty as to its original amount.

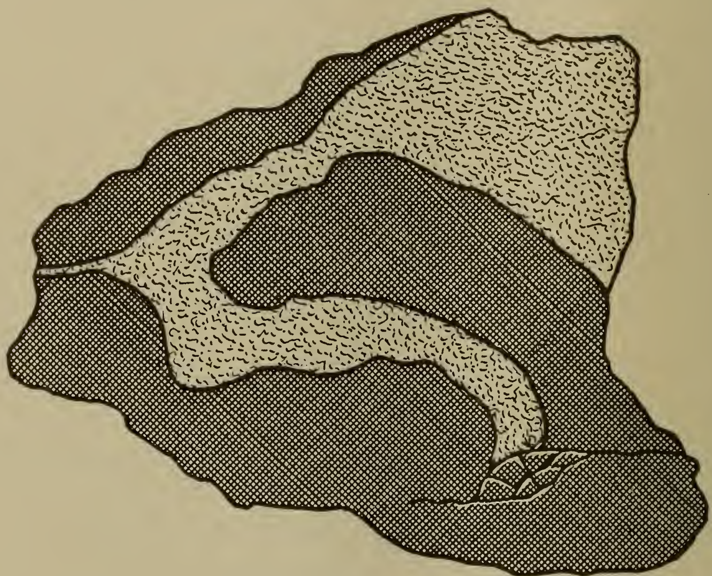

Fig. 11 Natural size drawing of a hand specimen of corroded limestone in pitchstone

The inclusions. Inclusions abound throughout the plug, both in the lava balls and in the intervening material. They are *all* of limestone, and limestone of but a single type. Though the knob stands surrounded by black shales, there are no shale inclusions in it. It is possible that there may be inclusions of earlier trap, and the coarser grained rock just mentioned may be an inclusion. But on this point we have no certain evidence.

The inclusions are of pure limestone, effervescing briskly and immediately with acid. They range in size up to masses a foot or more in diameter. In the balls they show but little sign of corrosive action, but in the glassy, intervening matter they are often considerably corroded by the igneous rock, resulting in the production of most curious shapes (figure 11).

In the specimen figured, the lava attack was probably from the front instead of from the right hand, thus lessening the amount of apparent corrosion, though a large margin remains. These corroded inclusions are in the pitchstone, while those in the balls show but little corrosion and but a trifling selvage of surrounding glass.

The two matters of chief interest concerning the inclusions are, the source of the limestone and the reason for the absence of other inclusions, especially those of shale.

The limestone of these inclusions is slightly reddened, presumably a result of heat from the lava, and is finely crystalline in texture, likely due to recrystallization on heating, though this is not certain. The inclusions are all of the one type of limestone. They must have been brought up from below ground by the rising lava, which must have passed through such a limestone formation during its ascent.

The only rock formation of the region which could have furnished such material is the Bald Mountain limestone of the eastern basin. In the western basin deposits we have the Hoyt and Amsterdam limestones, but they are separated by the great thickness of the Little Falls dolomite. Had the inclusions come from this series there would unquestionably have been an abundance of dolomite fragments in the lava, while actually there are none. But the Bald Mountain limestone has shales above and below. It also has many dolomite beds in its lower portion, so that it is surprising that there are none in the lava, if the inclusions really came from this formation. The question of the source of the inclusions becomes of much importance in the discussion of another problem, and we must later return to it.

The knob is surrounded by black shales, chiefly Normanskill, and it would seem that the lava must have risen through a large thickness of such shale. There are also frequent beds of hard, sandy grit in the shale. Under the circumstances the utter lack of recognizable shale inclusions is most astonishing. There are some large masses of shale involved with the lava but it is questionable if they can be regarded as inclusions. There are a few grains of quartz observable in the thin sections, and one patch consisting of a dozen such grains. It is possible that these came from the grits. But if so, it is surprising that there are not larger fragments from the same source, since these grits are exceedingly tough and well-cemented rocks.

Structural features. The dissection of the knob by quarrying operations has brought to light some new structural features. Woodworth described two faults along the margin of the knob, and his section (figure 9) shows his conception of the relations of lava and shale. But quarrying brought to light other masses of shale, involved with lava, within the knob. We found evidence of severe compressive disturbance and dislocation all through the lava mass of the knob, suggesting a number of minor dislocations throughout the mass, instead of merely the two which

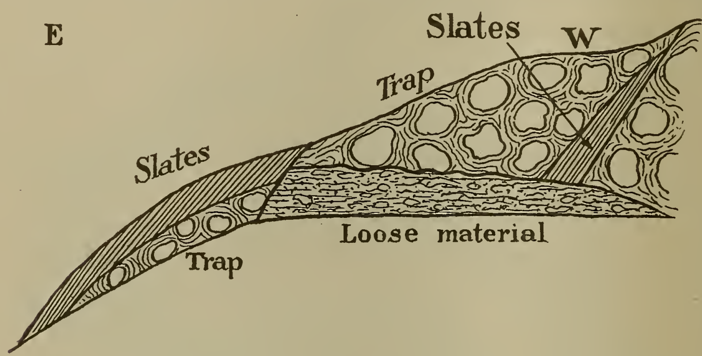

Fig. 12 Sketch of relations of shale and lava near the south end of the knob; shale overlying lava on the projecting point at the left, and a steep shale wedge in the lava midway

he saw, which were all that could have originally been recognized. A few sketches, and a comparison of them with our photograph of the knob (plate 18), will aid in the presentation of the details.

Figure 12 is a diagram of the south end of the quarried face of the knob, with a projecting point on the left which remains unquarried. On that point, slate overlies trap. Woodworth's section, in which trap overlays shale, was made a little farther south, and the remnants may be seen just over the roof of the engine house in plate 18. To the north of the point, shown in the sketch, trap makes the full height of the face and the shale has pinched out, but up this face runs another very steeply inclined, shale wedge, which runs nearly to the top before pinching out. Because of the section which Woodworth saw and figured, he judged a fault must lie between it and the main mass of the knob. But these other shale wedges within the trap mass suggest the query whether the shale in Woodworth's section may not also be a wedge with trap beneath.

At the extreme north edge of the knob is another projecting point, remaining unquarried. A portion of this point is shown at the extreme right in plate 18, though most of it did not get into the view. Figure 13 is a sketch of the relation here.

It is not certain whether the shale here was originally a wedge within the trap, or whether it formed the lower part of the shale cover of the trap on this side, into which a thin sheet of the lava was extruded, or whether it is due simply to dislocation.

The shear zones. In the nearly vertical shale wedge shown at the right in figure 12, the shaly material is greatly sheared and

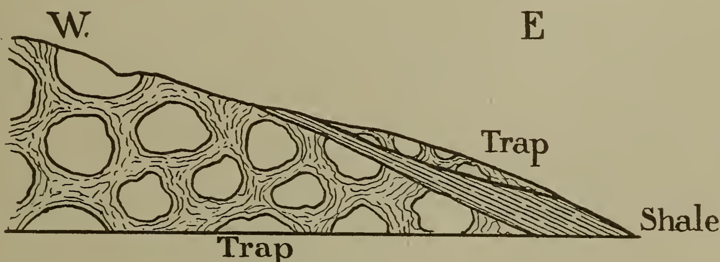

Fig. 13 Sketch of relations of shale and lava on point at the north end of the plug, showing a shale wedge with lava above and below

slickensided, as are also the trap surfaces adjoining the shale. The grooves and scratches on the slickensided surfaces are nearly horizontal in attitude, showing that these two parts of the knob have undergone lateral dislocation along a northwest-southeast line.

Within the northern half of the knob excavation has brought to light another great shear zone, nearly vertical and bearing north-south. There is no shale wedge here along which displacement has taken place, but merely a shearing past each other of the two adjacent parts of the knob, with production of a highly polished and striated contact surface. As in the previous instance, the striae are nearly horizontal, in no observed instance departing more than 20° from it. Here again there has been lateral displacement under conditions of load; in other words, it is inconceivable that these surfaces of hard trap rock could have been so thoroughly smoothed and polished when undergoing lateral slip past one another except under the weight of a considerable thickness of overlying rock.

In addition to these two great zones there are a host of minor shearing planes all through the knob, all showing slickensides on their faces, with usually horizontal striae. The lava balls always show exterior slickensides, and the intervening matter is everywhere greatly sheared.

During 1910 great sheared surfaces became exposed at the base of the excavations in the central part of the knob. The sheared material had considerable thickness and consisted of a mass of shaly, thin plates, with beautifully polished slickensides on all surfaces. The sheared zone had an easterly dip of about 40° and seemed to pass with that inclination entirely through the knob, from bottom to top. It was actually disclosed only for about one-third of the whole height. Plate 19 is a photograph of a portion of this sheared mass, showing the shaly material in considerable thickness. At the time it did not occur to us that this was the actual base of the trap, and we interpreted it as a shear zone within the mass. At subsequent visits it was found covered largely by quarry debris, so that it showed but poorly. We learned, however, that the material had been drilled into for a depth of 12 feet, in search for additional trap underneath, but that none had been found within that distance. This suggests that we have here the actual base of the lava. The material does not exactly resemble the ordinary shale, however, and there is some reason for the belief that it represents a sheared mixture of shale and lava. Here again the striae on the slickensides approach the horizontal.

There is one more indication of dislocation in the knob; its back seems to be broken. This becomes quite evident to the observer on the summit of the knob, looking down into the excavation. The main shear zone in the northern half of the knob trends N. 10° E., which is also the trend of the lava mass there. The southern half, however, trends N. 45° W. and its main shear zone does likewise. The knob appears as if it had been cracked in two midway by a vertical rent, and the two halves twisted out of alinement through an angle of 55°.

All the evidence indicates that the lava of the knob has experienced compressive dislocation of the same type as have the overthrust shales in whose midst it lies; of the same type and quite comparable in amount.

Plate 19

H. P. Cushing, photo, 1910

Slickensided shaly material on Stark's knob, as it appeared September 1, 1910. The position of the exposure is shown by the arrow in the previous plate.

If the great diagonal shear zone just described lies at the actual base of the lava, as we suspect, then the lava forms a short, sheet-like mass inclosed in the shales and dipping in conformity with them, as shown in figure 14.

This corresponds with Woodworth's original conception as may be seen by reference to his figure (figure 9, page 117). The present relief of the knob is due to erosion, the trap being more resistant than the adjacent shales. The shale wedges in the lava may be due to lava tongues running out into the shales from the main mass, or they may be the result of dislocation. There is shearing and faulting in plenty to account for all the observed phenomena.

The lava then seems to lie within the shales after the manner of an intrusive sheet; yet it can not possibly be a sheet. In the first place it is altogether too short. At the north it ends very

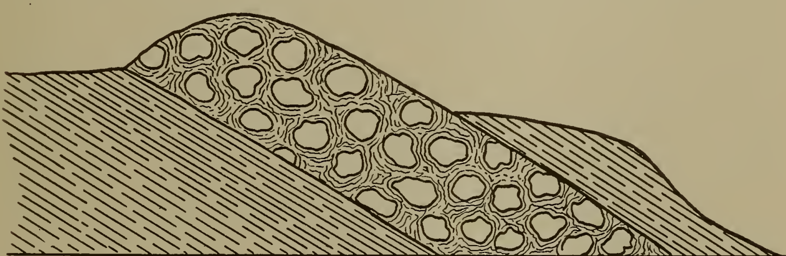

Fig. 14 Diagram of inferred relationship of lava and shales in Stark's knob

abruptly; a trench dug in the rock on the north slope of the knob is entirely in shale. At the south it becomes involved with shale wedges, and just south of the knob a poor exposure shows a thickness of about 1 foot of trap interbedded with the shales nevertheless here also the termination is fairly abrupt. The entire length along the strike from north to south is not over 200 yards. Moreover the nature of the lava itself, the ball structure and intervening glass, decisively negative any notion that we may be dealing with a sheet. The structure indicates surface lava, either a flow or a volcanic neck, a deposit in the throat of a volcano.

Microscopic characters of the lava. There are two chief varieties of the rock of the knob, the finely crystalline, dull, black rock of the balls, and the black glass of the intervening material. Both are locally amygdaloidal, but we saw no such material in place, all coming from the dumps. The study of the exposures has led us to the belief that the balls may have had a glassy crust originally, and that this has been sheared free from them by subsequent movements. At present all glassy material is between the balls and most of it has been much crushed by shearing.

Thin sections from the rock of the balls show a network of minute feldspar laths set in what is certainly in some cases, and probably in all, a glass base. In the finer grained rock from the margins of the balls the laths have a prominent radial or spherulitic arrangement. The somewhat coarser rock from the centers has the same arrangement, but less prominently. The laths are minute and not greatly twinned. In the coarser varieties extinctions up to 20° are shown and the feldspar is probably andesine-labradorite.

In none of the slides is there any determinable pyroxene, nor anything which especially suggests altered pyroxene. In the finer grained rock it is quite certain that no pyroxene ever crystallized out; in the coarser rock some may perhaps have done so, as there are small scattered patches of calcite and possibly alteration products between the feldspars which may have resulted from pyroxene alteration. But we regard it as most probable that the stage of crystallization of pyroxene had not been reached in any of the rock at the time of solidification.

All the slides show occasional, sharply bounded areas which have the outlines of porphyritic crystals. A number of these seem quite certainly original olivines; the outer form and the angles are precisely those of that mineral. This has led to the belief that all are probably original crystals of olivine. They show three different types of alteration.

In type 1 the mineral is entirely gone to a fine, light greenish, feebly polarizing aggregate, which seems unquestionable chlorite. A few individuals show traces of a mesh structure which suggests serpentine, but this is by no means the rule. This is the more usual alteration.

In type 2 the original mineral is entirely replaced by calcite, fairly coarsely crystallized, or else by calcite and quartz. This is the same mineral combination found in the amygdules.

Type 3 is the least common and seems to be a further stage of the alteration shown in type 1. The material is either brown and wholly opaque, or else this with the addition of tiny, colorless patches which show faint double refraction.

All the slides contain crystals of black, opaque material. There are occasional small crystals of pyrite. There is much minute, dustlike material, especially in the glass, which may be magnetite, though it wholly lacks metallic luster, perhaps because of its minuteness. There is also much somewhat coarser material, of irregular outline which we should like to identify as graphite. The chemical analysis indicates a large content of carbon in some form, but in reflected light this material does not show a metallic luster such as graphite possesses, but takes on an even, whitish sheen which we are unable to compare with anything we have ever seen in thin section. It seems present in the slides in about the proper quantity to account for the carbon shown by the analysis and may be graphitoid, or some other carbonaceous residue, instead of graphite.

All the slides contain much calcite. It fills the amygdules, it occurs in irregular patches throughout the balls, and it solidly welds up the numerous cracks which run everywhere through the lava.

The calcite in the cracks gives clear evidence of the deformation to which the rock has been subjected since it solidified. It shows everywhere the close-set, multiple twinning, and the undulatory extinction produced by the deforming stresses.

At the borders of the limestone inclusions in the balls a slight chilling effect is manifest, and a narrow zone of glass containing much finely divided, black, opaque matter has developed. A slight amount of corrosion has also occurred, small fragments of the limestone appearing separated from the main mass and in all stages of solution in the lava, the resulting product being a clear, light green glass. Examples of partially corroded limestone surrounded by such glass are shown, together with others which suggest the utter disappearance of the limestone fragments, the glass indicating their original presence. The limestone has also been recrystallized by the action of the lava, the border of the inclusion being more coarsely crystalline than the interior.

The pitchstone which constitutes the intervening material is black, but becomes a clear, light green glass in thin section. It is perfectly clear and unaltered, a matter of some surprise when it is recalled how completely the olivines are altered. Except in the vicinity of limestone inclusions, it has been sheared and shows its condition of strain by being doubly refracting. It is locally packed with tiny opaque inclusions, perhaps magnetite, shows an occasional pyrite crystal, and frequent irregularly bounded individuals of the material that we are assuming to be graphitic. At the contacts with limestone inclusions, clear evidence of limestone absorption is shown by the production of a zone of mingled material, calcite and glass, the relative proportions of which vary with distance from the contact. The glass is lighter in color and no longer clear glass, but full of very tiny crystals, often spherulitic, which are altogether too tiny for exact determination, but which appear to be feldspar. The addition of lime to the melt seems to have lowered the temperature of solidification sufficiently to permit at least the beginning of feldspar crystallization, while elsewhere the material solidified as glass. This intermediate zone is unquestionably one produced by direct solvent attack of the lava upon the limestone, and is thus corroborative of the evidence of this attack previously given.

The amygdules in the glass have the appearance of small, round, black bodies, when whole; when broken across, the interior filling is light colored but dull looking and not so white as in the case of the amygdules in the balls. The filling is the same in both cases, either wholly calcite, or else calcite with some quartz, both of fairly coarse grain.

Chemical composition. Since the rock from the centers of the large lava balls seemed in quite fresh and unaltered condition, except for the olivine, it was confidently expected that a chemical analysis would definitely show the composition of the lava, and would be attended by no especial difficulty. But analysis developed the presence of a considerable amount of carbon in the rock, rendering determination of ferrous iron very difficult, and showed also the presence of a large quantity of water. This also was difficult of exact determination. But Professor Morley has labored indefatigably at the problem. The ferrous iron was finally determined by bichromate titration. Professor Morley states that the results can not be vouched for to the single drop, as with permanganate, but that the uncertainty is not great; that he can not hope that the accuracy of the three determinations, Fe_2O_3, FeO and H_2O+ is as great as that of the others but that he has every reason to believe in their reasonable accuracy. Our indebtedness to him for the painstaking labor and the eventual very satisfactory result is most emphatically expressed.

The water is no doubt present as a constituent of the glass. The interest attaching to the presence of carbon more than compensates for the slight uncertainty introduced into the analysis.

SiO_2	47.55
Al_2O_3	16.65
Fe_2O_3	4.94
FeO	5.12
MgO	5.63
CaO	4.77
Na_2O	4.20
K_2O	2.52
H_2O+	5.57
H_2O-	0.24
TiO_2	0.87
P_2O_5	0.27
Cl	0.10
F	0.06
S	0.01
MnO	0.46
C	0.80
$CaCO_3$	0.34
Total	100.10

Selected rock from the center of one of the large lava balls, as free as possible from calcite. E. W. Morley, analyst.

The calculated norm of the rock would be

Orthoclase	15.01	Olivine	12.64
Albite	33.01	Magnetite	7.19
Anorthite	18.90	Ilmenite	1.67
Nepheline	1.42	Apatite	0.67
Diopside	2.48		

Totalling 92.99 per cent; the residue consisting of water, carbon and calcium carbonate. The rock classifies in

Class 2, Dosalane	Rang 3, Andase
Order 5, Germanare	Subrang 4, Andose.

It is thus a member of a very large rock group, of diabasic or basaltic composition. It is quite near some of the Newark traps, that from Medford, Mass., analyzed by Merrill for example, though it is a more basic rock than the average Newark traps, which run from 52 to 53 per cent of silica.

The carbon[1] content was a wholly unexpected result. Gaseous compounds of carbon are emitted by most cooling lavas, but a considerable carbon content in the cold lava is most exceptional. Inquiry as to its source is naturally suggested.

The knob is surrounded by black shales, which at once suggest themselves as a possible source. There are no recognizable shale inclusions in the lava, but it might be possible that the explosive action of the eruption should have mingled a certain content of comminuted shale with it. The thin sections however give no suggestion of any such admixture, no shale particles being recognizable in them. And when it is recalled that, in such black shales, the entire content of carbonaceous matter does not usually exceed 5 per cent of the rock, it will be seen that the rock at the knob would of necessity contain from 15 to 20 per cent of shale, in order to give the carbon percentage shown on analysis, provided it came from this source. But neither the thin section, nor the chemical analysis give any suggestion of such an admixture.

A trifling amount of carbon may have been obtained from dissolved limestone, as this contains a small amount of organic matter; and the abundant opaque particles developed in the glass at the limestone contacts, definitely suggests something of the sort. But there is no evidence of a large amount of limestone corrosion, and the rock is low in lime, rather than high. It could not have obtained much carbon from this source.

There remain apparently two possible sources for the carbon. The heat of the intrusion may have liberated hydrocarbons from the shales below ground, which were then taken up by the lava, or the lava itself may have contained more carbon than usual originally, more than could be oxydized by the usual volcanic processes. Either process is unusual, but then the occurrence is itself unusual. Graphite does occur in igneous rocks, as for example in some of the Adirondack pegmatites. Its occurrence in meteorites is well

[1] Because of the interest attaching to the presence of carbon in an igneous rock, Dr H. S. Washington kindly volunteered to look over the thin sections, and to examine the insoluble black residues of the rock. In a letter received from him too late for incorporation in this report he states that the material is carbon, and is not graphite. He also makes the following suggestion to account for its presence, that it is not impossible that, under proper conditions of pressure and temperature, FeO will reduce Co^2. He calls attention to the limestone inclusions as the source of the CO^2, and notes that the carbon in the thin sections is in the glass, and not in the feldspars, hence associated with the iron-bearing portion of the rock.

known. It is quite possible therefore that it is here one of the primary minerals of the lava. But the comparatively large amount present, together with the rarity of its occurrence in igneous rocks, enforces caution in attributing such a source to it. In so far as possible derivation from the shale is concerned it must be stated that the associated shales in the vicinity of the knob show no indication of any loss of carbon due to action of the lava, or indeed of any change whatever, so that if we look to them as a source we must assume that the process only took place at greater depths. It would be a debatable question whether hydrocarbons, liberated from the shales by the heat of the intrusion, would migrate into the lava; whether they would not rather be driven away from it. Even if taken up why should they have been converted to graphite? All, or nearly all lavas contain carbon; but on cooling they give it off in combination with oxygen, or with hydrogen. Why an exception was made in this case we cannot say.

Is the lava in place? Stark's knob is a small mass of igneous rock inclosed in shales. The shales are greatly contorted and compressed everywhere, and the evidence, both structural and paleontologic, shows that they have been overthrust into the district from the east. The question naturally arises, May not the igneous rock have come into the region by overthrusting, along with the inclosing shales? We regret that we are unable definitely to answer this question. Were it true, certain of the structural features would receive a simple explanation. The shearing and dislocation of the rock would thus be accounted for, as well as its abrupt termination laterally, and the lack of dikes running out from it into the shales. We could understand the reason for the shale wedges inclosed in the lava. More latitude would be given in accounting for the inclusions, abundance of limestone of a single type and absence of all other rocks. The manner of occurrence in the shales, a short and comparatively thick mass of lava imprisoned in shales along their dip, would also not be so hard to understand. The shales are so cleaved that they usually come apart more readily on the cleavage planes than on the stratification. It is this character that makes it so difficult to collect fossils from them. It would seem that the explosive action of a volcanic vent breaking through them would have opened them vertically along the cleavage planes instead of following the incline of the dip.

If the lava solidified where it now rests, the only possible conception of the occurrence which at all fits the facts of the case is that it is a volcanic neck. But volcanic necks are usually nearly vertical, instead of quite inclined, as in this case; they usually cut across the bedding instead of following it; and they are usually filled with agglomerate, tuff or solid lava. We do not recall any account of a volcanic neck filled with material such as that at Stark's knob. The usual filling is generally much more distinctly fragmental in type and more diversified in character. On the other hand, we know of no reason why such material might not accumulate in a neck.

Many features of the rock of the knob recall very forcibly the characters of pillow lavas, characters produced (in many instances at least) in surface lavas when poured out so that they mingle with surface waters. Spheroidal masses of lava, production of glass, and explosive mixture with fragmental material from beneath, are the prominent characters of such lava flows. A great number of shrinkage cracks through the lava pillows is another feature possessed in common.

At Stark's knob there is no sign of the basal admixture with fragmental material, such as is found in many pillow lavas, unless indeed the shear zone material at the base may represent it, crushed beyond recognition, as an analysis perhaps suggests. Nor is the lava as highly altered as most pillow lavas are; yet this difference may be more apparent than real. Most such have been described from natural exposures, and exteriorly the rock at the knob was highly altered. The fresh material is due to quarrying and comes from many feet below the original surface.

Nor is the structure exactly comparable with that of pillow lavas, the chief difference being in the greater quantity of intervening material at the knob. We have seen that shearing has probably increased the apparent amount of this, the outer portions of the balls cracking and shearing away, especially where composed of glass. But when every allowance has been made for this it remains doubtful whether the balls were ever as closely packed and close fitting as in most pillow lavas.

In weighing the evidence for or against the lava being in place, with part of the evidence seeming to point one way and part the other, we must confess our inability to come to any definite conclusion in the matter. The overthrusting seems a priori so unlikely that our sympathies are entirely with the other view. But we can not relieve ourselves of the suspicion that it may, after all, be an overthrust mass, a fragment of a surface flow which came up through and was poured out upon a surface of limestone, thus acquiring its inclusions, and later on thrust westward coming to rest with rocks with which it had originally little to do.

The inclusions. The difficulty of accounting for the limestone inclusions in the lava has already been mentioned. The inclusions are many, and all of one kind of rock, which seems perhaps referable to the Bald Mountain limestone, but certainly to no other of the rock formations of the region. The knob lies in the midst of overthrust shales. Just what their thickness is at the spot we have no means of knowing; but it is quite likely considerable, since they extend 5 miles farther west before thinning out to disappearance. In considering the manner of overthrusting in such weak shales it seems reasonable, if not obligatory, to suppose that the thrust was carried by some strong, competent stratum, on top of which the shales were carried westward. The Bald Mountain limestone is the first formation of the sort beneath the Normanskill shale, in the eastern basin section, and it is therefore not unreasonable to suppose that it is present underneath the shales at Stark's knob. If so it probably rests on the western basin rocks, most likely on Canajoharie shale. That the structure as a whole is not so simple as this, that the shales are jumbled indiscriminately together to a certain extent, is shown by the presence of Schaghticoke (Dictyonema) shale in the midst of the Normanskill near the knob. Were fossils more abundant, many such mixtures might be found. This suggests that a confused mixture of shales may have moved west even beyond the competent stratum which carried them, falling and being pushed in front of the main mass. The Bald Mountain limestone therefore may, or may not, be present below ground at the knob. If it is present it lies nearer the surface than any other limestone, with shales both above and below; and it is likely also to be in somewhat shattered condition, so that it would readily furnish inclusions to an igneous rock rising through it. The limestone inclusions can therefore be plausibly accounted for on the theory that the lava is in place. The lack of inclusions of shale is not thus explained; but the carbon content of the lava may have come from the shale, and its failure to furnish inclusions may be due to the physical nature of the rock.

So far as the inclusions are concerned, therefore, they do not aid in the decision as to whether the lava is in place or is not.

If the drill should show that the Bald Mountain limestone was absent below ground at the knob, a quite different face would be put upon the matter. But the drill has not been at work in the vicinity.

The age of the lava. Since the suggestion was made that the igneous rock of the knob might have some significance in connection with the theory of the juvenile origin of the Saratoga waters, the question of the geologic age of the rock becomes of more moment than would otherwise be the case. Unfortunately precise data are quite lacking.

When Woodworth and Cushing considered this matter, at the time of the original description of the knob, a Newark (Triassic) age was suggested by each of them, independently, as most probable. Then, as now, the only positive statement that could be made is that the igneous rock must be younger than the shales which surround it. Even this is not necessarily true, if it has been overthrust. The shales are of Ordovicic age. There are known in New York three groups of igneous rocks which fulfil that age requirement, the dikes of the Champlain valley, the dikes of central New York, and the traps of the Newark series. The rock, in its characters, does not at all suggest the Champlain dikes; still less does it in any way resemble the peridotites of central New York; but it is quite similar to some phases of the Newark traps. Unless we referred it to the Newark we had no alternative but to regard it as representing igneous action of some other date, with no other known representatives in the State.

That still seems to us the most logical view to take in default of actual evidence to the contrary. The amount of deformation experienced by the knob seems a positive evidence of antiquity. The dislocations already described indicate deformation under load, under a considerable thickness of overlying rock which has since been eroded. The lava is of the effusive type, either a volcanic neck or a fragment of a lava flow. Since its formation it has been buried under other rock, deformed, and the overlying material removed by erosion. When or under what it was buried we have no means of knowing, since all trace of the material has since been removed; but if the lava is in place, continental deposits of Newark age seems the most likely supposition. It might have been later continental deposits. To be sure, the knob lies in a main valley of erosion surrounded by relatively weak rocks, so that conditions are favorable to rapid wear. But even making every allowance for that it still seems to us that the very oldest Tertiary is the youngest age that can possibly be ascribed to the rock, all the conditions considered. Since igneous action of such age, or of any Tertiary age, is wholly unknown in the eastern United States, a reference to the Newark seems to us more reasonable. Yet we candidly admit the peculiarity of the rock and its isolated occurrence, and have no quarrel with anyone who is disposed to take a different view. There is one character of the lava which suggests recency, and that is the unaltered and undevitrified character of the glass.

To sum up, the only definite statement that can be made concerning the knob is that it consists of a small mass of lava of effusive type. If it is in place it seems surely a volcanic neck or throat; if not in place it may be a fragment of a surface flow, overthrust from some locality to the east. If in place it is younger than the date of the overthrusting; if not in place it is older. If not in place we have no idea whence it came, nor are any other fragments known. It has some features in common with certain Newark trap flows and is like some of them in composition, though the composition differs from that of the average Newark trap. Clear structural evidence of much shearing and faulting of the knob, of such type as to indicate deformation under load, leads to the conviction that the lava can not be an especially recent one.

HISTORICAL GEOLOGY

BY H. P. CUSHING AND R. RUEDEMANN

Precambric. Our direct knowledge of the events of Precambric time in the region commences with the deposition of the Grenville series. These rocks are very widespread and very thick, with great amounts of shales and limestones and a lesser amount of sandstone. They must have been deposited on some floor of older rocks which has since been entirely destroyed by igneous action, or else yet remains to be discovered. Judging by their extent and thickness the series was probably deposited under marine conditions but, lacking fossils, there can be no certainty in the matter.

Following the deposit of the Grenville sediments the region was repeatedly invaded from beneath by great masses of igneous rock. The earliest and most widespread of these invasions was that of the Laurentian granite. Subsequently came invasions of anorthosite, syenite, granite and gabbro. These broke up the Grenville rocks into groups of fragments, apparently ate away and digested much of the basal portion of the sediments and caused the complete disappearance of their old floor of deposit.

There followed a very long period of erosion of the region during which it was above sea level. A great thickness of rock was worn away from the surface, bringing to daylight the tops of the great igneous masses which originally solidified much below the surface. The final effect of the long erosion period was to have reduced the entire region to one of low altitude and small relief. Toward the close of this erosion period renewed igneous activity resulted in the formation of the trap dikes.

Paleozoic history. The Adirondack region then developed a tendency to dome upwards centrally and to sag at the margins. These sagging margins passed from time to time beneath sea level and received accumulations of deposit. In these troughs the early Paleozoic sediments of the region were laid down. Oscillations of level were of frequent occurrence, accompanied by warping of the region. Submergence in the different troughs alternated; it was the rare exception that all were depressed at the same time. In this report the deposits of the Champlain-Hudson trough (the so-called "Chazy basin") chiefly concern us.

To the eastward of the Chazy basin downwarping developed one or more other troughs, in which deposits quite different from those of the Chazy basin were laid down. Since their formation these rocks have been overthrust to the west upon the rocks of the Chazy basin, and directly adjoin them upon the east.

CAMBRIC HISTORY

Chazy basin deposits. Potsdam sandstone. The first Paleozoic deposit of the Adirondack margins was the Potsdam sandstone, an accumulation of coarse, quartzose sands and gravels. The accumulation began first on the northeast, in Clinton county, and extended itself progressively to the west and to the south. Only the upper portion of the formation is found in the Saratoga region.

This upper portion contains marine fossils and must have been laid down in shallow marine waters. But marine fossils are lacking in the lower half of the formation, in Clinton county, and many of its characters suggest that it was laid down above sea level instead of below it. They suggest also that the climate was arid. But whether marine or not, the accumulation began because the district sagged down. This sagging began at the north and slowly extended southward up the Champlain trough, and westward up the St Lawrence trough.

The currents which transported these coarse sands and gravels must have been vigorous ones, suggesting rather strong relief of the land which lay to the south and west. All fine material was washed and blown to a distance.

The sands of the Potsdam are succeeded by the alternating sands and dolomites of the Theresa formation without any sign of a break between them. Erosion had lowered the bordering lands. Sand came down only intermittently and in less volume, and beds of dolomite began to be deposited. The sands steadily diminish in frequency and thickness, and thus the Theresa formation grades upward into the Little Falls dolomite. Both these formations are marine, but in both of them fossils are very rare, especially in the dolomite. The great reefs of Cryptozoon, which occur at many horizons, seem to indicate the likelihood of abundant life and to suggest that the scarcity of fossils is more likely due to unfavorable conditions for preservation than to their absence in the marine waters.

The Hoyt limestone is a local upper phase of the Theresa formation about Saratoga. It seems to represent a more offshore phase of the formation, and fossils are much more abundant than in the ordinary Theresa or the Little Falls dolomite. This may in part be due to the offshore character of the Hoyt, but it also suggests more favorable conditions of preservation.

These three formations are of extreme upper Cambric age (Ulrich would class them as Ozarkic), and are the only Cambric deposits that were laid down along the Champlain trough. Following their deposit mild uplift occurred and the troughs came above sea level, existed as land for a space, and were somewhat eroded. This erosion gently bevelled off the surface instead of deeply cutting into it, which suggests that the land was of low altitude.

ORDOVICIC HISTORY

The uplift just mentioned forms for the geologist the dividing plane between the New York Cambric formations and those classed as of Ordovicic age. No one has any clear idea in regard to the length of elapsed time which this uplift represents. Eventually the troughs became again depressed and occupied by marine waters; and in these, on all four sides of the Adirondack region, the various dolomite and limestone formations of the Beekmantown group were laid down. These are thickest and most complete in the Champlain trough which sagged more, and for a longer time, than the troughs on the other three sides of the Adirondacks. But the Beekmantown deposits of the Champlain trough do not occur in the Saratoga region, and hence do not especially concern us in this report. The Saratoga district is on the western margin of the trough, its axis lying to the eastward. The trough was submerged and emerged several times. The waters of some of the submergences overspread the Saratoga region, as in the case of the Little Falls submergence; but the others failed to reach the district. Apparently the Beekmantown waters fell just short of covering it. It is barely possible that the formation was thinly deposited and subsequently entirely worn away. Beekmantown rocks do not appear in the Saratoga section.

Emergence of all troughs followed the Beekmantown, the emergence being of unknown duration. Then the Champlain trough was depressed so that its northern portion passed below sea level and the marine limestones of the Chazy group were laid down. This depression seems not to have reached within 75 miles of the Saratoga region which remained persistently as an area of lowland throughout Beekmantown and Chazy time.

BLACK RIVER HISTORY

Apparently emergence of all troughs followed upon the Chazy depression. Because the immediate Saratoga region lacks deposits of Beekmantown and Chazy age, these episodes have been described as though each consisted of a single submergence and emergence. In reality minor oscillations of level took place within both groups. Depression of the troughs, in which the various formations of the Black River group were laid down, succeeded the Chazy emergence. In order of age the three chief formations of the Black River group are the Lowville, the Watertown, and the Amsterdam. Only the near shore edges of these formations are now exposed to view in New York. They are very patchy in distribution and were deposited along the oscillating margins of the troughs, now above sea level, now below. The thicker deposits of the central portions of the troughs are not shown in surface exposures today, but lie farther away from the Adirondacks, buried under a cover of later rocks.

The Amsterdam is the only Black River formation deposited over the Saratoga region. The margins of the Lowville and Watertown troughs did not quite reach the district, and the Amsterdam rests on the Little Falls dolomite. It is the oldest Ordovicic formation of the quadrangle. Between the deposition of the two the region stood as a land area on the margin of the Champlain trough. The small amount of erosion of the Little Falls surface during this long interval is indicative of low altitude of the land.

The pure limestone of the Amsterdam denotes also low altitude of the neighboring land. The abundance of marine fossils shows plentiful life in the waters.

Uplift followed Amsterdam deposition, the Saratoga region passing slightly above sea level.

Succeeding this uplift came the Trenton submergence. At first, beds of limestone and of blackish shale alternated with one another; but the limestone soon ceased and the great thickness of the Canajoharie shale of lower Trenton age slowly accumulated in the subsiding trough. The fossils are chiefly graptolites; open sea forms swept into the trough by marine currents which ran through it. Conditions were not favorable for an abundant and diversified marine fauna.

During this same time Trenton limestones were being deposited on the west side of the Adirondacks, in clearer seas which swarmed with marine organisms. Conditions on the two sides of the region were thus sharply contrasted.

In middle Trenton time the deeper Canajoharie sea which extended from the Mohawk valley northward through the Chazy–Saratoga basin into Canada and southward through the Hudson river region and as far south as the southern Appalachians, was probably drained for a brief period in this region, but soon again the shallow sea of the Schenectady period extended through the trough northward to an unknown extent, but undoubtedly across the Saratoga and Schuylerville quadrangles. The bottom of this trough kept sinking gradually, so that upward of 2000 feet of shallow water deposits could be accumulated in it in Schoharie and Schenectady counties.

In the following Utica period this region was probably again emerged, for no Utica deposits have as yet been recognized in the lower Mohawk and Hudson valleys, the so-called Utica beds of these regions all being now known to be of Canajoharie age. It is, however, also possible that a thin edge of the Utica formation reached here around the southern Adirondacks, but was again eroded before the Indian Ladder sea crept over this region from the south. This latter formation consists, at the Indian Ladder, mainly of soft shales with some sandstone and calcareous bands, and seems to have been deposited in a slightly deeper sea than the Schenectady beds.

As we have seen before, there are exposed in the shale belt rocks of two entirely different sets of formations which represent sedi-

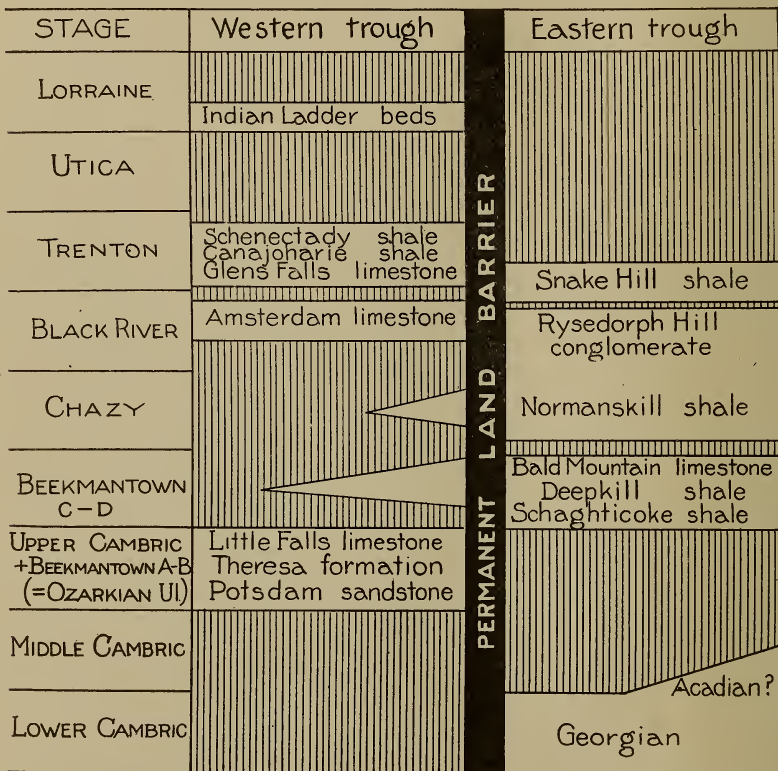

Fig. 15 Diagram of time relations of formations of the eastern and western troughs on the Saratoga-Schuylerville quadrangles. Shaded intervals indicate probable emergences

ments deposited in two different troughs, the western or lower Mohawk trough and the eastern or Levis trough; and if the Georgian beds represent a third trough (see above, page 114), even sediments of three basins.

We have represented in figure 15 the events going on in the two troughs, as far as the Saratoga and Schuylerville quadrangles are concerned, during Cambric and Ordovicic time, where the shaded periods represent emergences and the unshaded the submergences. It is seen at once that frequent oscillations took place in both basins and that the invasions of the sea and withdrawals did not take place simultaneously in both basins, but at very different times and apparently independently of each other. It appears, however, that there is recognizable a certain approximate alternation of the invasions of the sea in the two basins, indicating an east-west shifting of the seas in the troughs, such as has been observed in more complete development by Ulrich (1911, page 543) in the Ordovicic seas of the Appalachian valley troughs in east Tennessee. Moreover, the invasions came partly from the northeast or Atlantic basin and partly from the Gulf and Pacific basins.

The Lower and Middle Cambric time finds the western trough entirely drained of the sea, while at the same time a great mass of sediments was deposited to the east, the Georgian in the Levis trough, and the Acadian in still more easterly troughs, and possibly also to a limited extent in the Levis trough. This invasion came from the north.

In the Upper Cambric the scene of submergence shifted entirely into the neighboring westerly trough, where invasions first from the north and then from the southwest brought the Potsdam sandstone, the Hoyt limestone and Little Falls dolomite, while the eastern trough or Levis basin was at the same time raised above sea level.

During Beekmantown and Chazy time that part of the western trough now exposed was apparently drained in the area of the two quadrangles here described, the rocks of the two formations being absent between the Little Falls dolomite and the Amsterdam limestone. They are, however, present but a short distance north in the Ticonderoga-Crown Point region, and the sea in both the Beekmantown and Chazy times, nearly reached the quadrangles in this basin from the north, or it actually reached there in the more eastern, deeper parts of the trough which are now buried under the overthrust shales of the eastern trough. The sea did reach into this latitude and beyond, coming from the north, in the Levis trough, where the Schaghticoke and Deep Kill graptolite shales and possibly also the Bald Mountain limestone of upper Beekmantown age were deposited in Beekmantown time; and after a brief emergence, the Normanskill shale of Chazy age, which in its turn was followed after another short emergence by the sea depositing the Upper Normanskill shale with the Rysedorph Hill conglomerate and the Snake Hill shale. It appears that this whole group of Ordovicic seas of the Levis trough invaded from the north. The north connection is shown by the faunas and areal distribution of the Schaghticoke, Deep Kill and Normanskill shales, by the Atlantic faunas of the Rysedorph Hill conglomerate, and it is suggested by the fauna of the Snake Hill shale. Some of these, as the Deep Kill and Normanskill seas, had also connection with the Pacific ocean.

LATER PALEOZOIC HISTORY

Withdrawal of marine waters from the Saratoga region followed the deposit of the Indian Ladder shales and for the latter part of the Ordovicic period the region was above water. Then followed a time of considerable disturbance and uplift, the so-called Taconic revolution. Along a belt of country east of Saratoga the Ordovicic rocks were folded and upturned. About Saratoga this disturbance had no effect beyond giving the region somewhat increased altitude. During the following Paleozoic periods, Siluric, Devonic etc., the region continued its oscillations of level, but the times of depression did not carry the bottoms of the troughs below sea level. Paleozoic rocks younger than the Ordovicic, and all Mesozoic rocks, are absent from the western trough. It remained a trough during all this great lapse of time, but it remained above the level of the sea, even when its altitude was the lowest. Siluric and Devonic seas came into southern New York, but probably the waters of none of them covered Saratoga.

Apparently, however, the district remained at low altitude during all this time. No great thickness of Ordovicic rocks has been eroded from its surface. These shales of the upper Ordovicic are weak rocks and would be readily worn away under conditions of high altitude and free drainage. That they remain in such thickness as they have over so much of the district is demonstrative of small erosion since they were laid down.

It is quite probable that during oscillations which depressed the western trough, continental deposits accumulated in it and were subsequently worn away during the intervening periods of greater altitude. It is also possible that the overthrust shales of the more easterly troughs may have formerly extended farther west than they do now, and have covered the present exposures of the rocks of the western trough, from which they were afterward worn away. But this does not alter the fact that the Ordovicic shales are the last marine deposits known to have been deposited in the region; that the time which has elapsed since the close of the Ordovicic is enormously long; and that it seems inconceivable that these shales could remain over so much of the district and in such thickness, if the trough had ever had a high altitude for any considerable length of time.

CLOSING STAGE OF THE PALEOZOIC

It has long been held by geologists that the closing stages of the Paleozoic were, in eastern North America, a time of great earth disturbance. The district was uplifted and titled and at the same time the rocks were greatly folded and faulted by compressive forces. Folded rocks characterize the Appalachian district from Alabama to New York, and thence northeast to Gaspé.

It is quite certain that widespread uplift and Appalachian folding occurred at this time; but it would seem also that the preliminary stages of the folding, at least, had taken place long before. The sagging troughs of which we have been speaking, separated from one another by tracts of relative uplift, were the initial stages of this folding, which had been in progress all through the Paleozoic, as recently urged by Ulrich.[1]

The Paleozoic deposits of the lower Mohawk trough, the Western basin deposits of this report, were for some reason not greatly folded. They lie nearly flat today. They lay either too far west or without the zone of folding; or else the unyielding mass of the Adirondacks, which lay back of them, acted to prevent folding.

Did the thrust faulting which has carried the rocks of the Eastern basin into our district take place at this time, or not till later? We can not positively answer this question as yet; but we are in agreement with Ulrich in thinking that much of it is of later date and possibly very much later.

MESOZOIC HISTORY

During the entire Mesozoic the Saratoga region remained a land area. During the earlier portion of the time certain troughs along the east margin of the Appalachian region subsided and received a

[1] Geol. Soc. Am. Bul., 22:436–42.

large thickness of continental deposits. There is no vestige of such deposits in the lower Mohawk trough, and no direct evidence that they were ever deposited there. That a small thickness of such material may have been laid down in the trough at this date is by no means unlikely. The lower Mohawk trough, throughout its history, has had a tendency to sag, as contrasted with the territory east and west of it. It would not be forced or unnatural to assume that it participated somewhat in the sagging tendency which was so prominently manifest in some neighboring troughs to the east and south at this time. But if such deposits were formed here they were in such slight thickness that every vestige of them has since been removed by erosion.

When were the great faults of the eastern Adirondack region formed? And was the faulting wholly done during one single period of disturbance, or has repeated dislocation occurred along them since they were first formed?

The repeated sags of the western trough would tend to form fault breaks along its margins, separating it from the adjacent districts, the Adirondack region on the west for example, whose tendency has been to rise rather than to sag. It is therefore quite possible that faulting began in the district early in the Paleozoic. With every notable succeeding oscillation of level of the region it is highly probable that renewed faulting would take place along the breaks already in existence. Such an oscillation as that which brought the Paleozoic to a close would be sure to be accompanied by renewed movement along the fault planes.

The early Mesozoic rocks of the easterly Appalachian troughs have been greatly faulted since they were laid down. Obviously this faulting must be of later date than the deposition of the rocks. Most probably also this faulting was not confined to the mere troughs of deposit, but affected the adjacent territory also. It seems in the highest degree likely that further faulting occurred in the Champlain region at this time. The faults of the eastern Adirondack region are normal with nearly vertical fault planes, and these certain Mesozoic faults are of similar type.

On the other hand, the great overthrusts which have carried the rocks of the eastern basin west to their present position, covering much of the Schuylerville quadrangle, are faults of an entirely different type. The question arises as to the relative age of the two types of faulting. If the thrust faulting occurred before the normal faulting it would seem that the thrust-faulted territory should be also sliced by big normal faults. So far as we know, this is not the case. If on the other hand the thrust faulting is of a later date than the normal faulting, the overthrust materials should rest on a floor composed of the rocks of the western basin, these latter cut by normal faults which do not rise into the overlying, overthrust rocks.

We do not as yet possess decisive evidence on these points. Such as we do have, however, seems to indicate that, in the Saratoga region, the bulk of the thrust faulting is of later date than the normal faulting.

Cessation of the continental deposits of early Mesozoic age in the eastern troughs was probably brought about by renewed uplift. Then followed a long period of erosion whose final result was a rather thorough wearing down of the region to a comparatively level plain. Such an erosion plain is called a peneplain; a peneplain of this date was produced quite generally throughout the Appalachian region and eastern Canada, and it is reasonable to assume that it was also produced here.

CENOZOIC HISTORY

At the close of the Mesozoic the region was again uplifted. The low altitude peneplain which had been produced over the Adirondack region was elevated some 1500 feet or more, and rapid erosion of its surface began. Stream valleys were cut down and broadened. It is the depth of the valley cutting below the old peneplain level which enables us to estimate the amount of the uplift. The divides between the valleys, however, have been but little worn down during the time that has passed since the uplift. These divides rise now to uniform levels, the levels of the old peneplain. An observer, standing upon one of these divide summits and looking abroad to the others, receives the impression of standing upon the surface of a plain and has merely to imagine the valleys refilled with material in order to picture the plain as it was at the time of the uplift.

This old peneplained surface is readily made out over most of the Adirondack region. But in the extreme east it seems to fail and the divide summits rise to very discordant levels instead of being uniform. This we take to mean that here renewed slipping along the old faults occurred as a phase of the uplift; that the Champlain trough displayed anew its tendency to sag relative to the district to the west; that it was uplifted much less than the Adirondacks; and that the difference in amount was made possible by additional faulting, the easterly slices being thrown down relative to those west of them. The old fault scarps had been peneplained, along with the rest of the region. These further movements renewed them, and their prominence today is in part due to this late movement. The McGregor and Hoffman fronts of the Saratoga quadrangle would be much less imposing than they are had it not been for this.

It is by no means unlikely that further westward movement of the eastern basin rocks along the thrust fault planes also took place at this time.

During the first part of the Cenozoic, the Tertiary, minor oscillations of level took place in the region, but we lack the precise knowledge of just when and what they were. The close of the Tertiary was a time of additional uplift, considerably increasing the altitude of the region, not improbably with renewed faulting. Succeeding this the region was invaded by the ice sheets of the glacial period.

PLEISTOCENE HISTORY[1]

Judging from the glacial history of other parts of North America, the Saratoga region was probably covered by four or five successive ice sheets, which extended south from Labrador and occupied the territory. It was certainly occupied by two such sheets. Long interglacial periods intervened between these ice sheets. The glaciers interrupted the drainage, eroded the region somewhat, and on retreat left it cumbered with glacial deposits.

There were also oscillations of level during the glacial period, with loss of the initial high altitude. At the time of retreat of the last ice sheet the altitude of the region was lower than at present.

During the slow, northward retreat of the last ice sheet through the Hudson and Champlain valleys, various bodies of standing water occupied parts of the valley, south of the ice. The most southerly of these, and the one of greatest importance in the history of the Saratoga region, is known as Lake Albany. This was a fresh-water lake which extended as far south as Kingston

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[1] Two forthcoming reports by Professors Woodworth and Stoller on the Pleistocene of the Schuylerville and Saratoga quadrangles respectively will furnish full treatment of this portion of the geological history of the region.

Plate 20

H. P. Cushing, photo, 1910

Glacial boulder of Little Falls dolomite on the summit of a low drumloid hill, 3 miles west of Saratoga. The boulder stands on end and from a distance bears a strong resemblance to a monument shaft.

and, at its greatest extent, perhaps as far north as Whitehall. Fine clays were deposited in its waters and huge sand deltas were built along its shores by the streams which flowed into it. The great terraces of clay and sand which occur both east and west of the Hudson on the Saratoga and Schuylerville quadrangles, were laid down in its waters.

Lake Albany was succeeded by Lake Vermont. The latter lay, for the most part, north of the Saratoga region, in which its deposits are of little importance. In the Champlain valley its waters were lower than those of Lake Albany.

When the ice finally melted out of the Champlain valley the altitude was so much lower than now that the whole of the valley, and of the St Lawrence valley up to Lake Ontario, was below sea level and hence became occupied by marine waters. The whole Champlain-Hudson trough, however, was not thus depressed, Woodworth pointing out that the marine level probably did not reach south of Whitehall. Passing down Lake Champlain the marine beaches, and the marine fossils contained in the deposits, are found at steadily higher altitudes going north. At Plattsburg the marine waters reached a level some 300 feet above the present level of the lake. Woodworth does not believe that the trough south of Whitehall was submerged at this time. The trough seems to have oscillated on a pivot, depresssion at the north being coincident with elevation at the south, and vice versa. The pivotal line lies in the district between Whitehall and Albany. Since the ice vanished, the northern district has been steadily rising, the marine waters have been excluded from the Champlain and the upper St Lawrence valleys, and the St Lawrence estuary now ends at Montreal. This upward movement is likely still continuing. At the same time the lower Hudson valley seems to have been undergoing depression and its estuary lengthening. The Saratoga region is near the pivotal line and probably has been but little affected by these movements.

We can not leave Pleistocene matters without calling attention to one detail, the impressive glacial boulder shown in plate 20. It stands on the summit of a low drumlin, 3 miles due west from Saratoga, and is a conspicuous object. Viewed from a distance it looks like a monument, a simple shaft. It consists of a huge slab of Little Falls dolomite about 15 feet long, stood up on end. Some exfoliation has taken place, due to frost attack, but on the whole it has suffered comparatively little damage from the weather. For the glacier to leave a block of such shape in such position in such a commanding situation is highly exceptional, and it is one of the most striking objects of the kind that we have had the privilege of becoming acquainted with.

ECONOMIC GEOLOGY

BY H. P. CUSHING

Molding sand. There is a large annual output of molding sand from the general Hudson river region in New York, especially from the vicinity of Albany. The Schuylerville quadrangle makes a considerable contribution to this output, the material coming from near the surface, just underneath the soil. The sand forms part of the deposits of Lake Albany, which cover most of the surface below the 300 foot level on the Schuylerville quadrangle. For foundry purposes a sand must have a certain degree of refractoriness, cohesiveness, and porosity. Durability is also important, as is texture, but sands of considerable difference in size of grain may be used, the coarser for one kind of castings and the finer for another. The cohesiveness results from the sand occurring mixed with a certain percentage of clayey matter.

The deposits of molding sand have no great thickness, running from 8 or 9 inches up to a few feet thick. They commonly pass into worthless sand below. Good natural molding sands are not very common, so that the demand rather exceeds the supply.

Graphite. Mining for graphite has been carried on at two different localities on the Saratoga quadrangle, both of them quite recent projects. The older and larger of the two establishments is situated about 2 miles west of Porter Corners on the fault plane scarp of the Hoffmans fault. The other is 4 miles north of Saratoga Springs, and similarly situated on the McGregor fault plane scarp. The rock is quite similar at the two localities and seems to represent the same horizon in the Grenville series, a horizon in the quartzite formation. At the time of our study only the establishment at Porter Corners, the Empire Graphite Company, was in operation.

The Grenville beds at this locality have a N. 70° E. strike and a dip of from 30° to 50° to the south. The surface beds are soft and badly altered graphite and mica schists. They are quartz-feldspar-graphite and quartz-feldspar-phlogopite rocks, averaging 50 per cent quartz, 30 to 40 per cent of feldspar and the remainder a varying mixture of graphite and phlogopite with some apatite. The feldspars are so badly altered as to defy exact determination, but in part at least consist of plagioclase, likely oligoclase. Two beds are being utilized, or are capable of utilization, because of high graphite and low mica content. The upper bed, from 10 to 14 feet thick, has been the one chiefly worked up to date. The lower bed is much thinner. They are separated by a four-foot thickness of quartzite and thin limestone. Underneath is a much more solid bed of mica gneiss. The whole overlies massive quartzite and, like all the Grenville of the quadrangle, is more or less involved with the white, garnet-bearing granite which we regard as Laurentian. There has been an irregular output of graphite by this company since 1906, the production being exclusively flake graphite.

Much the same assemblage of rocks is shown at the pit of the Saratoga Graphite Company, but this is a newer enterprise with much less accomplished in the way of exploitation. Similar weak, altered schists are shown, of the same mineralogic make-up as at Porter Corners. We saw no rock so free from mica as are the two beds worked by the Empire company, though further exploration may disclose equally good material. The strike here is N 80° E, and 30° south dip, and the general similarity of the rock association strongly suggests that we are dealing with the same rock horizon.

Stone quarries. Quarries have been opened in several of the formations of the two quadrangles, in the Precambric granite and trap, in the Little Falls dolomite, the Amsterdam limestone, the Bald Mountain limestone, and the Northumberland volcanic plug.

Laurentian granite. A small quarry has been opened in the Laurentian white granite on the face of the McGregor fault plane scarp, 2 miles north of Saratoga. Like all the granite of the district it contains Grenville material in all stages of absorption. But the quantity of such inclusions of schist is much less here than elsewhere, the granite is massive and solid and of pleasing color, and there seems no reason why it should not make a most excellent structural material for many purposes. The location, however, is unfortunate, the quarry being situated well up the steep slope of the fault plane scarp, rendering cartage difficult and expensive.

Trap. A large quarry has been opened on one of the large diabase dikes where it is crossed by the North Creek branch of the railroad, 2 miles north of Saratoga. This dike is at least 100 feet wide on the average, and seems a very long one. Its average trend is N 20° E to N 25° E. For three quarters of a mile south of the quarry it can be followed unbroken, and north of the quarry we have picked it up so repeatedly when crossing its probable location as to convince ourselves that it must be the same dike throughout.

The rock is an ordinary diabase, an augite-feldspar-magnetite combination, lacking olivine. It shows everywhere considerable alteration, the feldspars much kaolinized and the augite largely changed to chlorite. These changes do not seem, however, to have seriously impaired the strength and toughness of the rock and should not, in our opinion, much impair its value as a road rock, for which purpose it has been chiefly used. Because of its width and great length this dike is capable of furnishing a large supply of road material. Where worked it is at low altitude and adjacent to a railroad. Its northern extension is less fortunately situated in these respects, and the same is true of the other dikes of trap in the Precambric. But since the demand for good trap for road-making purposes in New York at the present time is large, and the supply from the dikes in the Adirondack Precambric is the only available source in the State outside of Rockland county, it would seem as if there was opportunity for some development of the industry in the Saratoga region, owing to the unusual length and width of the dikes.

Dolomite. Two quarries have been opened in the upper beds of the Little Falls dolomite, within the limits of the two quadrangles, one on Maple avenue in the northern edge of Saratoga Springs, and the other a mile south of Wilton, Schuylerville quadrangle. In both cases the quarries are in the upper, light colored, coarsely crystalline beds of the formation. In the Maple avenue quarry a thickness of 22 feet of massive beds is exposed with a dip of about 5° to the southeast. The upper bed is full of chert; some of the lower beds are full of drusy cavities lined with dolomite crystals and containing crystals of clear, transparent quartz. A small fault is well shown in the quarry wall which is of interest because it seems very old. The throw is only 2 feet, but a strip of fault breccia about 6 inches wide was produced, which was subsequently solidly welded up by deposit of calcite from circulating waters, so that the rock is as strong and firm as it is anywhere in the quarry. The quarry is worked only intermittently, as demand for stone develops. It is used both for structural purposes and for road metal.

In the quarry near Wilton a twelve-foot thickness of similar beds is shown, also with cherts and drusy cavities containing quartz crystals. This quarry was opened chiefly for road metal purposes, and its product has been much used on the State roads of the vicinity. Some misapprehension as to the true nature of the rock exists in the minds of some people, as we frequently heard it referred to as a trap quarry, perhaps with the idea that any rock used on the roads must of necessity be trap. The material should make an acceptable road metal, though by no means so good as good trap.

Between 3 and 4 miles due west of Saratoga four quarries have been opened in the dolomite, on the west side of the Highland Park fault. The horizon in the formation is somewhat uncertain, but is judged to be near the summit, since Amsterdam limestone is the surface rock a short distance away to the south. The beds are massive for the most part, and consist of alternating courses of dark colored, fine grained stone, and lighter beds of coarser grain. At the time of our visit none of these quarries were being worked and we could obtain but little information regarding them. One of them is quite extensive and the stone is likely used both for structural purposes and for crushed stone.

Limestone. Three of the formations of the district have been quarried for limestone, the Hoyt and Amsterdam limestones of the western basin and the Bald Mountain limestone of the eastern basin.

Two quite large quarries have been worked in the Hoyt limestone, the Railroad quarry and the Hoyt quarry, the former 1 mile north and the latter 3 miles west of Saratoga Springs (plates 5 and 2). Neither has been worked for some years, and the earlier working was to supply lime chiefly for local use. The quarries are thus examples of what has happened on a large scale all over northern New York, the passing of local limekilns and the concentration of the lime industry at a few localities determined by favorable location and quantity and purity of the limestone.

The Amsterdam limestone has been quarried at Rowlands Mill and at Rock City Falls. It was burned for lime to some extent and also used for structural purposes and on the roads. At present it is being extensively quarried at Rock City Falls to furnish crushed stone for concrete.

The Bald Mountain limestone has been quarried at Bald mountain and at Middle Falls. On the west face of Bald mountain the steep western limb of the overturned anticline which this limestone forms there, produces a limestone face 100 feet high, which was well adapted to easy and rapid quarrying. The greater part of the material was burned for lime on the spot.

Ruedemann furnishes the following notes on quarries in this limestone noted by him:

The quarry at Middle Falls, which has furnished the fauna, is a small one, showing some 25 feet of heavy bedded limestone quite like that at Bald mountain. The beds are nearly horizontal. The quarry was long ago abandoned, but the material was probably used exclusively for lime.

A half mile west of Middle Falls, on the west bank of Batten kill, at the bend, is a much larger quarry, exposing a thickness of 50 feet of beds, 20 feet of dolomite beneath, and 30 feet of limestone above. The beds are here nearly vertical, with steep dip to west and northeast strike. One and one-fourth miles farther south is another large quarry, and a smaller one yet farther south. The bulk of the material quarried was burned for lime, but the less massive beds were also utilized in structural work. In the report on the first district Mather speaks of the quarries here, which were in active operation at that time.[1]

It is some 40 years since this industry lapsed. There is a large quantity of excellent limestone along this belt, and when the available material at Glens Falls approaches exhaustion, a revival of operations here is not unlikely.

Normanskill grits. There are several abandoned quarries in the grit bands of the Normanskill shales in the vicinity of Quaker Springs. These durable sandstones had a wide use all over the region for structural purposes, but the quarries have been idle for some 20 years.

MINERAL WATERS

The district centering at Saratoga Springs has long been famous for its mineral waters, and especially for its very distinctive, highly carbonated, saline waters. There are in addition numerous sulphur springs in the region, which would probably have a wider repute had the other waters not been also present.

The sulphur waters of the region all rise from the black shales (Canajoharie, Normanskill, Snake Hill), and taste strongly of sulphuretted hydrogen, derived no doubt from the decomposition of

[1] Geol. First Dist., p. 403.

the pyrite of these shales. Such waters are of frequent occurrence the world over; nevertheless such a large spring as the "White Sulphur" spring, near the south end of Saratoga lake, would have great notoriety in most districts.

About Saratoga these sulphur waters are plainly not deep-seated waters of any type; they come from no great distance below the surface, and have not reached a depth so great as the base of the shales. So soon as the drill passes through the shales into the dolomite beneath, the carbonated waters are met with, and would surely be mixed with the sulphur waters, had these reached to like depth.

The carbonated waters. There are few problems in geology more difficult than those concerned with the origin of the mineral waters of a specific region. The precise data which can be obtained are always comparatively few, and the problem must be dealt with by indirect methods. In discussing such questions much that is hypothetical creeps into the discussion unawares; and even in regard to certain fundamental matters our information is so far from being precise, that geologists are far from being in agreement concerning them. Certain things in regard to the occurrence and character of the Saratoga carbonated waters have been definitely ascertained and can be definitely set forth; beyond those we enter the realm of uncertainty and can only discuss probabilities or possibilities.

Control of the waters of the Saratoga region has recently passed into the hands of the State of New York, giving an opportunity for definite experimentation on a considerable water supply of unusual character, which has perhaps never before been equalled, and from which definite and certain information of much general interest is sure to come. Prior to this passing of control there had been a period of some 15 years duration of active drilling for mineral water for the purpose of extracting and vending the contained carbonic acid gas. This development took place in the district south and southwest of the village, mostly within a distance of 2 miles from it. A considerable number of wells were drilled, from nearly all of them the waters had to be pumped, and the amount of water so withdrawn annually was very large. Controversial questions arose which resulted in long and complicated litigation, questions such as the source of the waters, quantity of the supply, and underground arrangement of the waters. As an incidental result much detailed information was made public.

In a bulletin recently published by the State Museum, Professor Kemp has discussed in exhaustive fashion many phases of "The Mineral Waters of Saratoga."[1] An historical sketch is given, the known geographic extent of the waters stated, and the composition and character of the waters very fully treated, followed by a presentation of his personal views on the origin of the waters. It is no part of our purpose here to present a review or repetition of this most excellent piece of work, which may be obtained by anyone interested in the matter. But one or two phases of the problem do seem to us to merit additional treatment at this time.

Location. The region of abundant carbonated water centers round Saratoga. The original springs, outflowing at the surface, were chiefly in the village and were few in number, and their multiplication and extension has been due to the use of the drill. There has been much drilling in the village and even more to the south, between Saratoga and Ballston.[2]

The present springs near or at Saratoga may be conveniently separated into three groups (see accompanying map): (1) the Village group, comprising the line of springs in Saratoga, from the Red spring on the north, to the Congress and Washington on the south; (2) the South Broadway group, the wells of the Natural and Lincoln gas companies, about 1 mile south of the village; (3) the Geysers group, the springs clustered in the vicinity of Coesa creek, about 2 miles southwest of the village. In addition are isolated springs not included in any of the three groups, of which the Gurn spring on the Schuylerville quadrangle, about a mile southeast of Wilton and 6 miles northeast of Saratoga, has the most interest for us.

Geologic occurrence of the waters. The springs in the village all occur on, or in close proximity to, the surface trace of the Saratoga fault. Here are included the original springs, natural outlets of the rock waters. The fault is a trifling one from the standpoint of magnitude, as faults go in the region. Hence the association of the waters with this particular fault must be for a

[1] N. Y. State Mus. Bul. 159.

[2] See Bulletin 159, pages 7–9, for a more complete discussion of the known springs of the general region. One addition should be made to the list, the Vita spring, near the northeast edge of the Schuylerville quadrangle, 10 miles northeast of the Gurn spring, and *east* of the Hudson. The water is quite like that of the Gurn spring, carbonated, and distinctively of the Saratoga type

MAP SHOWING LOCATION OF SPRINGS AND WELLS IN SARATOGA SPRINGS, N.Y.

0 — ONE MILE — 1

BY

WM. R. HILL, JUNE 24, 1909

reason entirely apart from amount of throw. The significant feature of the fault is that shales are the surface rocks on the downthrow side, and are continuously at the surface to the east for many miles.

Away from the fault the drill discloses carbonated water underground only in territory where shales are the surface rocks, territory to the east of the fault. No doubt, in this shale-covered region, the waters have wider distribution than the drill has yet shown. But there is no reason to believe that there will be any disclosure to conflict with the statement that the water is restricted to shale-covered territory, in which the impervious shales prevent its ascension to the surface; that such territory has its western boundary at the Saratoga fault and that the water can and does make its way to the surface along this fault; and that carbonated water has never been found on the west side of this fault and will never be found there.[1] East of the fault the waters are imprisoned under the shales. The Saratoga fault furnishes the line for escape of the water simply because it happens to be the particular fault which terminates the shales on the west.

The rock which acts as the reservoir for storing the water is the Little Falls dolomite. Invariably the drill discovers it in that rock. Occasionally, owing to local conditions, the drill reached water in the Amsterdam limestone, and was not sent down into the Little Falls beneath. But the evidence is clear in such cases that the water had worked its way up into the limestone from the dolomite along some fissure. Only one well in the whole region, the Hathorn bore, has been carried through the dolomite. This well discovered water in the Potsdam underneath. Unfortunately no sample of this water was saved and analyzed, but Mr Hathorn's statement concerning it is that it was water of the general Saratoga type, but very weakly mineralized; hence the well was sealed far above it and only water from the dolomite admitted. In general, the dolomite is not a porous rock. Certain of its beds have a calcite cement and weather porous; but in the drill cores they all seem solid and impervious, and it seems probable that the water supply in the formation is all contained in cracks and fissures, instead of in porous layers.

[1] The Ainsworth well in Saratoga is a possible exception to the above statement since it may be located a few feet west of the fault line. It is, however, practically on the fault line.

Northward from Saratoga the broad belt of Hudson Valley shale narrows rather rapidly, and north of Fort Edward but little of it remains. In the Champlain valley but a few patches of shales remain, nothing like a continuous cover. Judging by the Saratoga vicinity, such a cover is necessary both to prevent the free escape of the mineral water and to prevent its admixture with overwhelming quantities of surface water. This fact would seem to account for the nonappearance of these carbonated waters to the north.

The rocks of the general region dip to the south, hence the shale cover thickens southward and the mineral waters, if present, are at a steadily increasing depth below the surface. In the village the driller reported for the Star spring bore, only a short distance east of the fault line, that the bottom of the shale was 100 feet below ground, 38 feet drift, 62 feet shale, then limestone. The Natural Company wells on South Broadway show an average of 140 feet of drift and 50 to 100 feet of shale before reaching limestone. At the Geysers the limestone is still deeper. The Hathorn No. 2 well reported 23 feet of drift and 432 feet of shale above the limestone. At Ballston the shale is 200 feet thicker than this, and the limestone correspondingly deeper. The waters then extend to the south of Saratoga under the shales, but the depth of drilling necessary to reach them steadily increases in that direction, and away from the Saratoga vicinity they do not come to the surface naturally. They likewise extend probably far to the east under the thickening shale cover.

It is by no means unlikely that to the south of Saratoga, the water may extend to the west of the Saratoga fault. As has been previously stated, the course of this particular fault south of Saratoga is conjectural, but on the assumption that it runs down to Ballston, as provisionally mapped, it would be quite possible for the waters to pass beyond it and appear west of it. About Ballston shales are the surface rocks on both sides of the fault, with the Little Falls dolomite below ground on each side under a protecting shale cover. Along the south margin of the Saratoga quadrangle the shales extend entirely across the sheet from east to west, the southerly dip of the rocks giving rise to shales at the surface in each of the successive fault strips. The diagram, figure 16, will explain the assumed course of the underground water, better than can be done verbally.

It is possible to account for the presence of these waters, held imprisoned beneath the shales, in one of two ways. They may be regarded as deep-seated waters which have arisen from depth along the line of the Saratoga fault and spread from the fault plane into the dolomite, in which rock they migrated away from the fault plane and down the dip, to the east and south, thus changing from ascending to descending waters; or they may be regarded as having come from some source to the east and as having used the dolomite as their route toward the west, coming up the dip of the rock as ascending waters, the head supplied from the hills east of the Hudson. Until the Saratoga fault is reached the water is confined to the dolomite by the impervious cover of

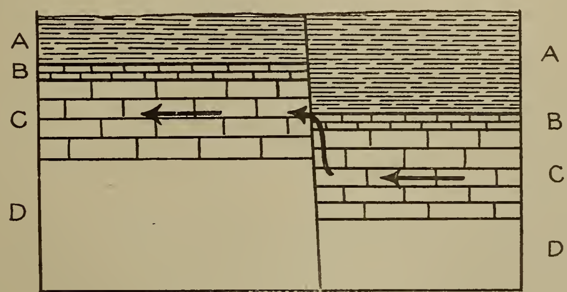

Fig. 16 Diagram of the supposed extension of the Saratoga fault at Ballston. The arrows indicate the course taken by the underground water which comes from the east through the dolomite, rises along the fault fracture to the level of the dolomite on the west (upthrow) side, and passes into that toward the west, the shales preventing it from coming all the way to the surface.

A = Canajoharie shale, B = Amsterdam limestone, C = Little Falls dolomite D = Hoyt, Theresa and Potsdam formations in order.

overlying shale, and at the fault the first opportunity to escape to the surface is given. On this view the waters do not ascend from any great depth along the fault, but merely follow it to the surface from their fissures in the dolomite, below ground on the east side of the fault. In our opinion this latter view represents the true state of the case. Ruedemann was the first to see this clearly, his opinion being based on his structural work in the district of overthrusting east of the Hudson. He has prepared a statement of his views, which appear on page 165 of this bulletin. We are in cordial agreement with his reasoning as there outlined. As previously stated, we think the lack of carbonated waters to the north is readily explained by the lack of the shale cover, so that any possible carbonated water in the region would become diluted and swamped in the general mass of the ground water, which would readily work its way downward into the rocks of the region and drown out the other water. Of his theory in regard to the origin of the carbon dioxid, we shall have more to say shortly.

The shale cover. It is not pretended that the shale cover is absolutely impervious to water; in fact it is known not to be. In places, especially near its thinned, western edge, where less than 100 feet thick, springs of carbonated water broke through it, arising probably along joint cracks. Such cracks are present in all shales, especially near the ground surface, and are present here. A few furnished channels for rising carbonated waters. Enough of them became filled with ground water to transmit the general ground water head to the carbonated rock waters beneath, thus influencing their direction of movement. The matter is perhaps best illustrated by a discussion of the conditions at the South Broadway wells.

Inspection of the topographic map will show that the ground occupied by the Natural and Lincoln companies a mile south of the village along South Broadway, is relatively elevated as compared with the line of occurrence of the springs in the village, or as compared with the springs along Coesa creek. The levels near South Broadway are between 310 and 320 feet, with a summit of something over 320 feet elevation just east of South Broadway. In the village the well heads have a general elevation of 280 feet, which is also the average elevation along Coesa creek. From South Broadway the ground level falls both toward the village and toward Coesa creek (the normal *ground water* level should also fall toward each from a high point on South Broadway), and if this ground water head is transmitted down through the shales along occasional cracks into the waters contained in the dolomite, as seems highly probable, the tendency in these carbonated waters would be also to move away from the South Broadway region toward the village and toward Coesa creek. That is, the water pressures would lend themselves to such a movement of the underground waters and would oppose a contrary movement. If the water head on South Broadway were interfered with and lowered by any cause, this natural flow would be correspondingly weakened and the water levels in the village and along the east side of Coesa creek sympathetically lowered.

The generalized section of the rocks above the Little Falls dolomite shown in the Natural Company's wells on South Broadway is as follows:

140 feet Drift	Soil and gray sand	25 feet
	Quicksand	45 feet
	Clay	20 feet
	Sand and gravel	50 feet
118 feet Canajoharie shale	Shale 75 feet	
	Alternating shale and limestone 43 feet	
36 feet Amsterdam limestone		
Little Falls dolomite		

The lowermost drift deposit at the locality is a heavy bed of porous sand and gravel, capped by a twenty-foot thickness of quite impervious Albany clay. When first entered by the drill these lower sands were full of carbonated water, which had got into the sand because of one or more natural springs coming up through the shales and which had been retained there by the cover of impervious clay. There was here a local reservoir of carbonated water at a horizon 150 feet or more above the water in the dolomite. At an early date in the history of the operations of the Natural company this upper reservoir was pumped out and so remained. When full it served to transmit the pressures of the ground waters in the upper sands down to the rock waters beneath; when exhausted of water the hydrostatic column was interrupted and this pressure no longer transmitted, with the result that the normal water head was lost, what amounted to a great cone of depression was produced, and the water levels in the village and on the east side of Coesa creek were affected.

The presence of original carbonated water in this sand we take to demonstrate the presence of outlets for the water in the shales below. The carbonated water came up through the shales and filled the sand reservoir under the clay.

Since pumping ceased all over the district, as it passed under State control, this pumped out reservoir in the sand has been slowly refilling. When such refilling shall be complete and the old ground water head thus restored, we look to see a demonstration of its effect upon the water levels in the lower grounds.

The waters in the dolomite are no doubt following crevices for the most part. There must be a host of these, and the connections between the different water-bearing crevices must vary greatly in character. Some must be very direct and others extremely indirect. So long as they were controlled by the same general hydrostatic head they would be expected to show close sympathy in action, whether the connection were direct or indirect. With the loss of this general head, controlling the water pressures in all the crevices, this close sympathy of action would no longer obtain. Active pumping of a well might quickly and notably affect the water level of a neighboring well, and not at all affect another well equally near to the first but in a different direction from it. In the first case the underground connections would be fairly direct; in the second case very indirect; but under the circumstances the conclusion that there was no underground connection whatever between the two wells, might not be justified at all.

Have the waters a common source? The carbonated waters of the Saratoga region are peculiar. The abundance of carbon dioxid, of sodium chlorid, and of calcium, magnesium and sodium bicarbonates, and the almost entire lack of sulphates, gives them a character which is possessed by few other natural waters the world over. Taken together with their restricted distribution, this leads irresistibly to the conclusion that they have a common source. They distinctly impress us as mixed waters, waters which have not obtained all their dissolved mineral matter at the same time and place and which, probably in the latter stages of their underground journey, have become diluted in varying degree with fresh, surface waters. The varying degree of mineralization of the waters of the different springs, when compared with one another, is most simply and naturally accounted for in this way. The statement which has been made in regard to some of the pumped wells, that unusually prolonged and vigorous pumping of a well results in bringing to the surface brine of increased strength, seems to us to point to the same thing. Under these circumstances less dilution with fresher surface waters takes place than is normal for the particular well.

By a common source we mean that the original mineralization of the waters takes place in a specific underground area of unknown extent, owing to specific chemical reactions of unknown nature, and that from this area the waters follow a definite route to the surface, no doubt undergoing further mineralization on their way. Our conception of the route is that from a deep-seated source to the east the waters follow the upward inclines of the thrust planes and of the beds of dolomite, which eventually lead them to the surface in the Saratoga region; that in the dolomite the waters make their way along a multitude of fissures or cracks in the rocks, constituting a great network of channels which are all connected when considered at large, but which locally may, or may not, be closely connected.

Summary. We hold it to be demonstrated that the Saratoga carbonated waters, as they exist underground, are confined to the district which has a shale cover, underneath which they are held imprisoned in the Little Falls dolomite; and that the water originally found escape, to a limited amount, along the Saratoga fault and through the shales near their thinned western edge. Certain of these outlets were known, but there were also others in unknown number hidden under cover of overlying glacial drift. We hold it to be in the highest degree probable that the waters are mixed waters, that they have in part a deep-seated source, and that they come from the east, following up the thrust planes and up the dip of the dolomite beds, utilizing fractures in the dolomite as their channels. When their path is blocked by a normal fault, they utilize it to rise to the level of the dolomite on the upthrow or west side, and then reenter the dolomite. When the particular fault which terminates the shales on the west is reached, the waters rise to the surface along it wherever the ground levels permit. The village springs and the Gurn spring are located on such a fault. The Vita spring and the springs along Coesa creek rise through the shales, quite possibly along a fault, though the fault has not been demonstrated in either case.

When we pass from these matters to those concerned with the amount and permanence of the water supply, and to the question of the origin of the waters, we are dealing with questions of quite another sort, questions regarding which wide differences of opinion prevail, and concerning which we can obtain little or no direct information.

The water supply. Below ground the manufacture of this mineral water either has, or has not, ceased. It is still being manufactured, or it is not. If not, then we are dealing with a stored water supply of definite amount, which can be pumped out and exhausted, just as underground stocks of petroleum and of natural gas become exhausted. It seems to us unlikely that this is a case of the kind. Springs have been flowing at Saratoga ever since the region became known, and for an unknown length of time prior to that, no doubt a very long time. There is much natural escape and there are too many outlets to allow us to believe that the original supply, however large, could have withstood such a steady drain on its resources. We are rather forced to the belief that we are dealing with a great, underground water circulation in natural equilibrium, inflow and outflow being equal, and that the rate of natural outflow measures for us the rate of manufacture and of inflow. If this be true, there is not the same danger of exhaustion of the supply that there would be in the other case. But this is a very different thing from saying that the supply is unlimited and can be drawn on indefinitely at a rate much in excess of the normal circulation.

The origin of the water. Any discussion of this problem must of necessity be almost wholly theoretical. Our lack of definite knowledge of too many of the factors is too great to permit it to be otherwise. We refer to it at all here only because Professor Kemp has exhaustively discussed the problem in Bulletin 159, and because we wish briefly to consider one or two points made in that discussion. A brief synopsis of his argument must precede.

Kemp gives a very exhaustive discussion of the composition of the Saratoga waters. Omitting minor constituents, they are characterized by high content of chlorids and bicarbonates of sodium, calcium and magnesium, high content of uncombined carbon dioxid, and extremely small content of sulphates. He distinguishes three divisions of underground water from the standpoint of origin, meteoric waters derived from the rainfall, magmatic waters derived from cooling igneous rocks, and connate waters, generally marine waters buried in the rocks at the time of deposit and retained in them. Then by a process of elimination he rules out connate waters as a possible contributing source for the Saratoga waters, in whole or part, because they lack sulphates in solution. He dismisses meteoric waters as a possible source of the carbon dioxid and the chlorids, because we know of no chemical method by which they might be produced in such waters in the Saratoga region; and he finally concludes that these constituents are therefore likely of magmatic origin. His summing up is as follows:

> The explanation which appeals most strongly to the writer is that the carbonic acid gas, the chlorids, bromids, iodids, fluorids and sodium carbonate are deep-seated. The sodium carbonate might in part or in whole be dissolved from the feldspars in the old crystalline rocks. The carbonated waters take on calcium and magnesium carbonates from the limestones encountered in their upward journey, more especially from the Little Falls dolomite.

Our purpose here is not at all to express disagreement with these views of Kemp. We are not sure that we do disagree with them. Kemp has made an important contribution to the geology of the mineral waters of the region, by elaborating a definite theory concerning their origin. We simply wish to emphasize the difficulty and complexity of the subject, and our lack of definite data regarding it, and to suggest alternative views in one or two respects.

We feel quite confident, in the first place, that the volcanic knob at Northumberland is no evidence whatever of underground igneous action, in the general region, of sufficient recency to have any bearing on the question of the existence of present-day juvenile waters underground. It does not show that such water does not exist. But we think that the evidence for the presence of such water is wholly independent of the presence of the plug, and is neither strengthened nor weakened by it.

We quite agree that the carbon dioxid and the chlorids have a deep-seated source, but we think Ruedemann's suggestion as to the possibility of the carbon dioxid arising from deep-seated metamorphism of the rocks is quite worthy of consideration as an alternative hypothesis to the juvenile one.

The tangential pressures which gave rise to the overthrusts may have operated up to very recent times and may still be in operation. They must aid in metamorphosing deeply buried sediments. In such sediments there is generally much lime, partly as beds of pure limestone, partly in impure limestones, calcareous shales and calcareous sandstones. In regions of metamorphosed sediments it is the common experience to find the limestone formations converted to marble and retaining all their original carbon dioxid. The impure limestones and the calcareous shales, on the contrary, recrystallize to schists containing little or no calcium carbonate. but much calcium silicate in such minerals as pyroxenes, amphiboles, garnets etc., and we must assume that the calcium has been recombined and carbon dioxid set free. Kemp lists this process as one of the methods of the manufacture of uncombined carbon dioxid below ground, and states its possible applicability to the Saratoga region, but dismisses it as, to his mind, less likely than an igneous source. But when combined with Ruedemann's theory of the eastern source of the water it seems to us to take on greater probability and to be worth considering as a source of the gas.

Nor do we feel at all certain that connate waters are to be entirely ruled out of the question. The lack of sulphates in the

Saratoga waters is a very real difficulty. But the possibility of the sulphates having been precipitated somewhere along the long route of water ascent, may be suggested as an alternative view. Such a reaction as that investigated by Hilgard some years ago, a solution of sodium sulphate in presence of free carbonic acid dissolving calcium carbonate, with formation of sodium carbonate and precipitation of calcium sulphate (gypsum), suggests what may conceivably have happened.[1] That connate waters of marine derivation must have originally contained sulphates does not seem to us open to question; but it does not necessarily follow that, on admixture with other waters, the sulphates should persist in solution. We do not urge this as a probability but merely as a possibility. It does not seem to us proven that the Saratoga waters may not receive a contribution from a connate source.

These observations are in no sense a criticism of Kemp's theory, but merely intended to emphasize the difficulty and complexity of the subject. The two main difficulties in the way of unqualified acceptance of the juvenile origin of the Saratoga waters are that they are not thermal waters, and that we have no direct evidence of igneous action of any recency in the vicinity, or anywhere else in the eastern United States. It is the latter fact particularly that makes us cautious and causes us to reserve judgment and leads to the suggestion of other possibilities. The theory is not condemned by us; we regard it as very likely true. But we do not as yet see our way to its unreserved acceptance.

A paragraph at the close of Dr F. W. Clarke's discussion of Mineral Wells and Springs so well expresses our state of mind that we conclude by quoting it.[2]

And yet, notwithstanding all that has been written on the subject, the controversy over the genesis of hot springs is not closed. What is the origin of the carbon dioxid with which so many mineral waters are heavily charged? In some instances, doubtless, it is derived from the decomposition of limestones, but in others this explanation can not suffice. Here and there it may be, to use Suess's expression, "juvenile," and evidence of the deep-seated origin of a spring. Again, whence comes the sodium chlorid of waters that flow from sources where it could not have been previously laid down? These questions, and others like them, still await satisfactory answers.

[1] Am. Jour. Sci., 4th ser., 1896, 2:100.
[2] U. S. Geol. Surv., Bul. 491, p. 203.

RELATIONS OF THE SARATOGA MINERAL SPRINGS TO THE STRUCTURE OF THE SHALE BELT OF THE UPPER HUDSON VALLEY.

BY R. RUEDEMANN

The study of the shale belt of the Saratoga and Schuylerville quadrangles by the writer has brought out certain structural features which appear to explain the accumulation of the mineral waters in the Saratoga region.

The salient facts in the distribution of the mineral water for the discussion here presented are : (1) the mineral springs are distributed in a belt extending in a northeast-southwest direction, from the Gurn spring to Ballston Spa and farther south (Albany?) ; (2) the waters come up in connection with or near a fault line, extending in this direction; (3) the water does not occur west of this fault line, but is found far to the east of it (Quaker spring and Vita spring) ; (4) it is stored in a series of limestone, dolomite and sandstone formations underlying a shale formaton.

The investigations of the writer have now shown that the shales forming the surface rocks east from the springs fault belong to two entirely different series or sets of formations which were deposited in two separate basins.

The western set begins on top with the Canajoharie shale. This is underlain by the Glens Falls and Amsterdam limestones, the Hoyt limestone, Little Falls dolomite and Potsdam sandstone, the latter resting on Precambric rocks, mostly gneiss.

This western series, which sinks in one or two step faults from the Precambric area of the Adirondacks to the level of the Saratoga plain, is but little disturbed and the beds are but little tilted and not folded. It continues eastward to an unknown extent, which, however, must be considerable since only the western edge of the old basin is now exposed on the surface. Undoubtedly it extends as far as the eastern hill region, as indicated in sections.

Only 3 miles east of Saratoga an entirely different set of formations begins to appear on the surface. In this set most formations are represented by shale, namely, the Trenton by the Snake Hill shale, the Chazy by Normanskill shale, the Beekmantown by Bald Mountain limestone (thin), Deep Kill shales (thick) and Schaghticoke shale, and the Cambric by the Georgian shales, slates, limestones and quartzites. This set of formations, as their lithologic character and faunas show, has been formed in another more easterly basin. The diastrophic movements, which raised the Green and Taconic mountains, have not only intensely crumpled and folded this entire mass, but also shoved it a great distance westward until it has overridden the western set of formations to within a few miles of Saratoga.

The combined effect of this great overthrusting of the eastern shale masses on the western set of formations has evidently been that the limestones of the latter have been buried under an immense mass of shales. At Mechanicville, for instance, only a few miles from the western edge of this shale mass, a well was sunk 1400 feet through these shales without reaching their bottom. Further, this mass undoubtedly forced the western set of rocks downward, a process which was helped by step faults such as occur at Saratoga farther west.

We thus get a set of limestone and sandstone formations that descends gradually eastward to greater and greater depths, becoming all the time buried under greater masses of impervious shales. The mineral waters, which for good reasons are considered as coming from the east, find thus a channel in the jointed and broken limestones and porous sandstones, gradually rising westward until they strike the Precambric block at Saratoga, where they rise along the Spring fault and through the relatively thin shale cover to the surface from the storage basin that is formed in the fault block upon which the eastern part of Saratoga Springs stands. This underground course of the water is indicated in the sections on plate of sections by the blue line.

The pressure necessary to bring the waters on the long journey from the east through this underground channel is probably supplied through the head obtained from the mountain regions in the east.

It is not intended to explain the origin of the carbonated mineral waters by the structure of this basin, although the possibility may be suggested that the limestones may in their eastward descent reach such depths that they may become subject to metamorphism through which the carbonic acid and some of the salts become dissociated. At any rate, the known regional metamorphism of the rocks of the eastern trough in the Taconic-Green mountain regions is a fact worth remembering in this connection, and the

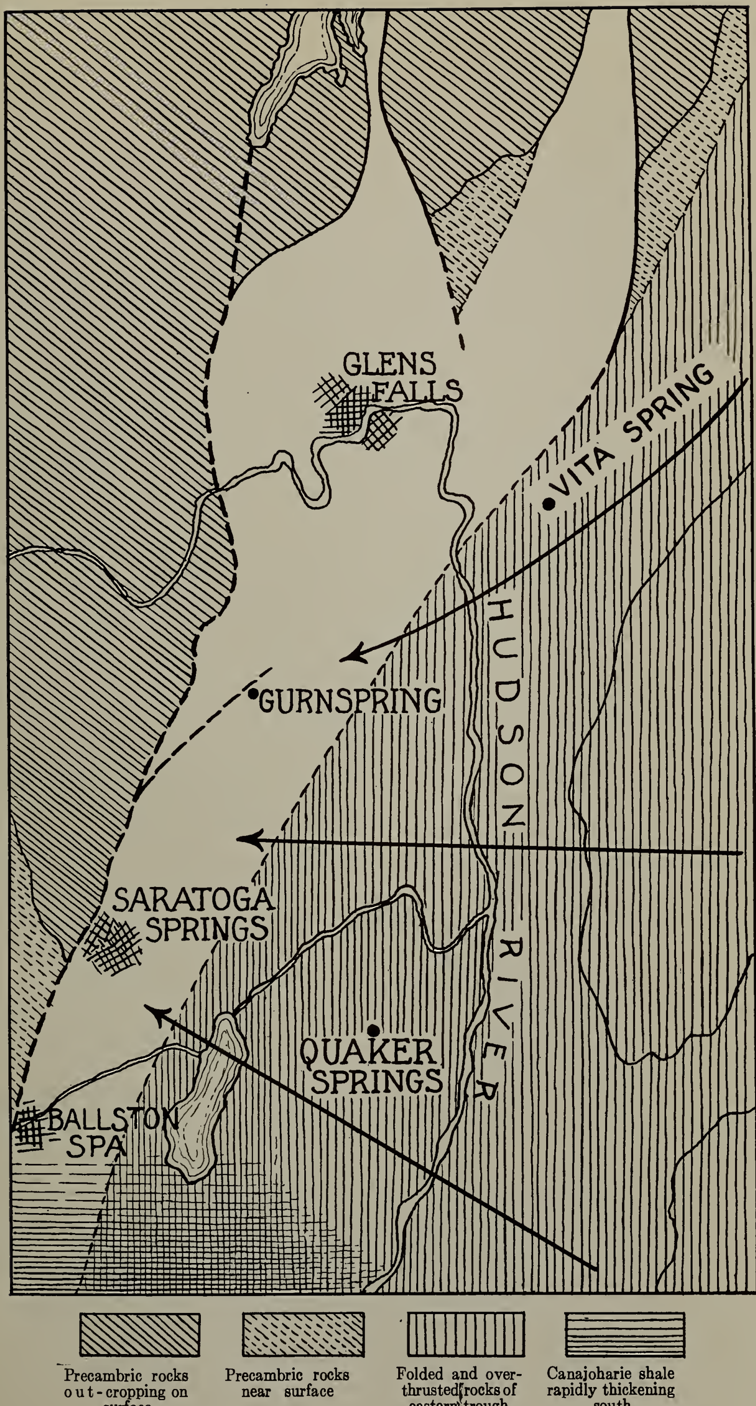

Fig. 17 Diagram to show the blocking of the mineral waters in the Saratoga region by fault blocks of Precambric rocks in the north and west and the thickening cover of shales at the east and south.

possibility of the continuation to the present time of these processes that metamorphose the shales, limestone and sandstones into schists and gneisses in the depths of the mountains is not at all disproved. At the same time it is also possible that these same limestones and sandstones come within the influence of deep-seated, still heated igneous rocks, thence deriving their carbonic acid, and at the same time that they gather " connate " waters (original sea water deposited with the rocks) from a large area and held in the depths, to which they descend, through the thick covering masses of shales.

One naturally asks here why these waters only come up in the Gurnspring-Saratoga-Ballston belt, a stretch altogether not more that about 12 miles long. The geologic structure of the region is responsible for this phenomenon (see diagram, text fig. 17).

South of Ballston the shales again thicken rapidly on account of the southward dip of the beds, until at Schenectady they reach no doubt more than 3000 feet in thickness, thus shutting the waters off from the surface to the south of the Saratoga mineral springs region. Northward of this region the structural relations are not yet well understood and the reasons for the absence of the springs not apparent. At Glens Falls the " Trenton " and Black River limestones come again to the surface but without bringing any mineral water. This outcrop is apparently the southern spur of a fault block. It probably fails to intercept the mineral waters coming from the east because it lies west of another large fault, which is indicated by the Fort Ann spur of Precambric rocks and which extends close to or into the crumpled shales of the eastern basin, thus shutting off the mineral waters from access to more western regions or to the surface altogether. We have seen before that the Precambric rocks west of the Spring fault form a barrier for the waters in that direction and that the thick masses of shales east of the area serve there as a competent cover. The Spring belt is thus shut in on all four sides by either thick masses of shales (east and south) or barriers of Precambric rocks (west and north) and in the belt itself the waters are brought nearest to the surface in following the routes of least resistance.

CONTROL OF DEVELOPMENT AND HISTORY OF SARATOGA REGION BY THE GEOLOGY

BY R. RUEDEMANN

Saratoga and Schuylerville (the original Saratoga) quadrangles are historic ground. The battles of Bemis Heights and Saratoga (present Schuylerville) which have been cited among the fifteen decisive battles in the history of the world, were fought on this ground, and these, more than any other events of the Revolutionary War, the people of the United States have to thank for their freedom.

Any one who studies this region with an interest both for its fascinating history and its geology, can not fail to be impressed by the close relationship between the course of the historic events and the geology of the region. In view of the especial interest attaching to anything connected with the history of Saratoga, it may therefore be well briefly to point out the influence of the geology upon (1) the development of the region, and (2) the course of the struggle between the American and British armies.

The Hudson river formed the natural highway through this country not only for the Indians but also throughout colonial history. The early Dutch settlers followed this stream into the northern woods and first settled the fertile bottom lands and then the edge of the rich land on top of the clay banks laid down in Lake Albany. When Burgoyne pressed into the country he found only this thin first line of settlements, while back of the river on both sides there extended the primeval forests. Here the Dutch reached the northern limit of their settlements and gave names to the Moses kill, Snook kill, Batten kill and Fish kill. Later, New England pioneers came from the east through the mountain passes provided by the Batten kill.

While the fertile clay plains and bottom lands along the river attracted the first farming population, another geologic influence created a second center of settlement in the western, less fertile, sand region of these quadrangles. This was the mineral springs that issued at the foot of the fault scarp at Saratoga and which were already highly valued by the Indians for their healing qualities. Because of them Saratoga Springs, in the middle of the former century, became the foremost summer resort of the continent and the largest town on the two quadrangles, and on their account the railroad trunk line from the Hudson river through the Champlain valley to the St Lawrence, the Delaware & Hudson Railroad, does not follow the Hudson river to Fort Edward as one would expect, but leaves it at Mechanicville to swing far to the west. Thus again the influence of the faults which bring up the mineral waters of Saratoga is strongly felt in the distribution of the population of the quadrangles and the direction of the principal railroad.

A third geologic agent which controls the distribution of the settlements and which is constantly growing in importance is the presence of rapids and waterfalls in the rivers and brooks. These are due to two causes in the region, first, the greater erosive power of the Hudson river over that of its tributaries on both sides, whereby the latter flow in "hanging valleys" and are forced to reach the level of the river along a series of falls and rapids in their lowest course; and, second, the rejuvenation of the rivers by the glacial period, in consequence of which in their new, immature courses they frequently meet ridges of harder rock protruding into the glacial deposits from the irregular preglacial surface, and in such places are dammed up and form falls or rapids. Thus Schuylerville and Victory Mills grew up where Fish creek falls into the deeper Hudson valley; Ballston Spa where the Kayaderosseras creek falls into the old preglacial fault depression of the Saratoga fault; Thomson and Fort Miller where the Hudson river plunges over ridges of shales, chert and grit that block its way. Likewise Gansevoort is located where the Snook kill strikes a line of anticlinal ridges and overthrusts in the Canajoharie shale and supplies water power by a waterfall, and Clark Mills where the Batten kill crosses a ridge of harder Normanskill rocks; Middle Falls where it is held up and falls over the Bald Mountain limestone, and Greenwich where the olive grits of the Georgian formations force the Batten kill to form rapids and supply water power. It is thus seen that every village in the shale belt is located where water power is produced by the geologic structure of the region.

Equally interesting with the control of the settling of this region by its geology is that of the events of the battles of Saratoga by the same agency.

Burgoyne had two routes to reach the Hudson river and thereby Albany, his objective point; namely, first, the deep depression extending from Whitehall to Fort Edward and caused largely by the downfaulting of the Ordovicic rocks at the eastern base of the Adirondacks and, second, the fault basin of Lake George. He selected the former and entered the swamp region of Wood creek, following this creek with its immature swampy drainage up toward the Hudson. Here it was extremely easy to impede his progress by cutting trees and throwing them across the road, an opportunity of which the Americans made the fullest use. Burgoyne wasted months of valuable time and his best energy and provisions in these swamps of glacial origin. When he finally reached the Hudson he followed it on the east side until he found the place where at Thomson the river falls over a ridge of harder Normanskill shale below which a bridge could be easily built. After crossing he was again forced to the river bank by the only road available, while deep ravines cut into the thick clays of Lake Albany made excellent opportunity for a defensive position for the American army. Such a position was selected at Bemis Heights.

On the other side of the river towers Willard mountain, an erosion remnant due to the hardness of the grits and cherts of Normanskill age that compose the syncline. From this bold mountain every movement of the British army could be easily seen by the patriot Willard and signalled to General Gates.

After his defeat, Burgoyne retreated leisurely and sullenly up the river. Hessian officers advised him to leave his cannon and baggage behind and save the army by a forced retreat by way of Lake George, but the obstinate though brave general decided to return by the crossing at Thomson, allowing by his slow and undecided action the Americans to overtake him and, in using the peculiarly favorable topography of the locality, which is due to its remarkable geology, to prepare a trap for him. The most important feature of this topography is that just above the Thomson crossing a volcanic rock, known as the Northumberland volcanic plug, juts out prominently toward the river, so that it has complete command of the crossing and at the same time prevents an army from passing under it at the west bank of the river. This important strategic point was occupied by Colonel Stark. It, and Fellows's batteries which could be advantageously placed on the bluffs of Albany clay on the opposite bank of the river, were, with Morgan's sharpshooters in the woods to the west of the army, the principal means of forcing Burgoyne to surrender. Thus we see that the peculiar combination of a ford over a shale ridge, a volcanic rock close by and bluffs of clay aided greatly in bringing about the decisive victory of Saratoga.

INDEX

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New York State Museum

John M. Clarke, Director

Museum Bulletin 170

GEOLOGY OF THE NORTH CREEK QUADRANGLE, WARREN COUNTY, NEW YORK

BY

WILLIAM J. MILLER

New York State Education Department

Science Division, March 12, 1913

Hon. Andrew S. Draper LL.D.

Commissioner of Education

SIR: I have the honor to transmit herewith a manuscript entitled *Geology of the North Creek Quadrangle, Warren County, New York,* which has been prepared by Dr William J. Miller, a member of the temporary staff of this Division. Accompanyiing the manuscript are the necessary maps for its adequate illustration.

I recommend the publication of this manuscript as a bulletin of the State Museum.

Very respectfully

JOHN M. CLARKE

Director

STATE OF NEW YORK

EDUCATION DEPARTMENT

COMMISSIONER'S ROOM

Approved for publication this 18th day of March 1913

Commissioner of Education

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BY

WILLIAM J. MILLER

INTRODUCTION

The North Creek quadrangle comprises an area of approximately 215 square miles in the southeastern Adirondacks. The map [1] covers one-sixteenth of a square degree which lies wholly within Warren county. A branch of the Delaware and Hudson Railroad from Saratoga Springs passes through the region from southeast to northwest, with a terminus at North Creek village. This railroad is an important entry into the southeastern Adirondacks, especially for summer tourists.

The principal villages of the quadrangle are North Creek, Horicon, Pottersville, Chestertown, Wevertown, and Johnsburg with Warrensburg very close to the southeastern corner. Considered as a region so distinctly within the Adirondack Precambric rock area, it is unusally thickly settled and well supplied with roads, which have been a great help in making a detailed study of the complicated geologic features of the quadrangle. Agriculture is the principal industry, though during the summer months a large number of visitors come to the numerous hotels and summer boarding places, especially those in the larger villages and around the lakes. This region, like the Adirondacks in general, was formerly heavily forested but the first growth timber has largely been cut off so that the lumbering industry is now nothing like that of earlier years.

[1] See map in pocket of back cover of this bulletin.

GENERAL TOPOGRAPHY AND GEOLOGY

As compared with the general Adirondack area, the North Creek quadrangle presents a rather unique assemblage of topographic forms. Long, prominent mountain ridges, usually with northeast-southwest trend, which are so common in the eastern Adirondacks, are practically absent from the quadrangle, and instead the dominant topography form is the separate, rounded mountain mass or dome which stands out conspicuously above the surrounding country. Such domes, which are numerous and widespread especially in the southern two-thirds of the region, are commonly from 500 to 800 feet high. The highest and largest of these domes is Crane mountain which rises 2000 feet above the immediately surrounding country. Among the other more notable examples are Hackensack,[1] Moon, Potter, No. 9, Little, Huckleberry, Kelm, Chase, Prospect, Mill, and Stockton mountains. These domes always form striking features of the landscape. Ridges do occur but they are seldom more than two or three miles long and do not assume their usual importance in Adirondack topography. This peculiar North Creek topography has largely been produced by a very irregular system of numerous faults in combination with a rather widespread though "patchy" distribution of comparatively weak Grenville strata. In the succeeding pages these matters are described in detail. The maximum range in elevation is from about 640 feet, where the Hudson river leaves the quadrangle, to 3254 feet at the summit of Crane mountain. Many of the mountain tops show altitudes ranging from 1200 to 2000 feet.

The Hudson river, which is the largest stream in the southeastern Adirondacks, passes through the midst of the quadrangle from the northwest to the southeast. The Schroon river, which is one of the chief tributaries of the upper Hudson, cuts across the northeastern portion of the area and thence along the western side of the adjoining Bolton sheet to reenter the North Creek sheet at the extreme southeastern corner near Warrensburg. It is worthy of note that the Schroon river, in the northern portion of the area, flows at a level 200 feet below that of the Hudson to which it is tributary. All the drainage of the quadrangle passes into the Hudson, though that of fully two-thirds of the region does so by first entering the Schroon river. Within the map limits, scarcely a stream of any consequence enters the Hudson from the east, while several streams of considerable size, such as Patterson brook, Glen brook, and Mill creek, enter it from the west.

[1] On the map the name of this mountain is misspelled.

Quite typical Adirondack lakes and ponds are fairly abundant, about thirty of them being represented on the map. The largest is Schroon lake, only the southern end of which lies within the map limits. The others range in size from small ponds to lakes two or three miles long such as Friends and Loon lakes.

From the geologic standpoint, the North Creek quadrangle is of more than the usual interest because of both the rock types and structures. With the single exception of the anorthosite, all the important rock formations of the eastern Adirondacks are abundantly represented. Except for the superficial glacial and recent deposits, the rocks of the quadrangle are all of Precambric age, and nearly all are highly metamorphosed, foliated, and folded.

Following is a list of all the rock formations, except the Pleistocene, given in the regular geological order of relative ages:

5 Diabase: wholly nonmetamorphosed, occurring in comparatively small, narrow dikes, and clearly cutting all the other rocks of the region.

4 Pegmatite: wholly nonmetamorphosed, dikelike masses cutting all rocks except the diabase.

3 Gabbro: more or less metamorphosed, occurring in stocks or dikes and cutting all types of the syenite-granite and Grenville series.

2 Syenite-granite group: distinctly gneissoid rocks, representing several facies of a single great intrusive mass, and clearly younger than the Grenville.

1 Grenville series: highly metamorphosed and foliated sedimentary rocks, including crystalline limestone, quartzite, and various dark to light colored gneisses. These are the oldest rocks of the region.

In spite of the rugged character of the topography, the accessibility of all parts of the quadrangle and the general excellence of rock exposures have afforded an unusual opportunity for detailed field work. Many important geologic relationships are very clearly exhibited.

Following are the principal papers which have a more or less direct bearing upon the geology of the quadrangle:

1842 Emmons. Geology of the Second District, N. Y.

1897 Kemp & Newland. Preliminary Report on the Geology of Washington, Warren and Parts of Essex and Hamilton Counties. In 17th Annual Rep't N. Y. State Geologist.

1898 Kemp, Newland & Hill. Preliminary Report on the Geology of Hamilton, Warren, and Washington Counties. In 18th Annual Rep't N. Y. State Geologist.

1899 Kemp & Hill. Preliminary Report on the Pre-Cambrian Formations in Parts of Warren, Saratoga, Fulton, and Montgomery Counties. In 19th Annual Rep't N. Y. State Geologist.

1911 Miller, W. J. Exfoliation Domes in Warren County, N. Y. In N. Y. State Mus. Bul. 149, p. 187–94.

1911 Miller, W. J. Pre-Glacial Course of the Upper Hudson River. In Bul. Geol. Soc. Amer., *22*: 177–86.

ROCKS OF THE REGION

GRENVILLE SERIES

General statements. The Grenville series comprises the oldest known rocks of the area. They consist of a great mass of highly metamorphosed and crystallized sediments such as original limestones, sandstones, and shales which have been changed to crystalline limestone or marble, quartzite, and various gneisses. Since it has not yet been definitely determined whether these rocks should be classed as Archeozoic or Proterozoic in age, the noncommittal term " Precambric " is employed. The weight of evidence is on the side of their Archeozoic age and it is certain that they can not be of late Proterozoic age.

Among the proofs for the sedimentary origin of these rocks within the quadrangle are: (1) the very character of much of the material such as limestone and quartzite which can not possibly have been of igneous origin; (2) the arrangement of the rocks in distinct beds of widely different composition and often sharply alternating; and (3) the common occurrence of graphite (crystallized carbon) as flakes scattered through much of the rock, such graphite being almost certainly of organic origin.

Grenville strata are known to be of common occurrence throughout the Adirondack mountain region and this, together with the facts that the total thickness of these strata is very great and that they extend over not only the Adirondack area but also a vast extent of Canada, make it certain that those very ancient strata are of marine origin. It is evident that the Grenville sediments were laid down upon an ocean floor of even greater age but, in spite of twenty years of painstaking field work by several investigators, no trace of that ancient floor has certainly been recognized. Nor has any trace of that very ancient land, whose wearing down by erosion furnished the Grenville sediments, been found. It seems probable that those

Pregrenville masses were either engulfed by the later great intrusions or that they were changed beyond recognition.

Areal distribution of the Grenville. About four-ninths of the surface rock of the quadrangle is Grenville, provided we include the Grenville which makes up considerable portions of the areas of mixed gneisses. It should be noted that the Grenville here assumes much more prominence than is usually the case in the Adirondacks. Also, as the accompanying map shows, the Grenville is very widespread in its distribution, it being least prominently developed in the central and northern portions. A striking feature is the "patchy" character of its distribution, this being due to the very irregular manner in which the great igneous intrusions broke through and cut to pieces the Grenville strata.

The three types of Grenville which are sufficiently different to allow of separate representation on the geologic map are:

1 Crystalline limestone which is generally associated with dark hornblende gneiss, this latter rock often being garnetiferous.
2 Quartzite in thin to thick beds and usually more or less interbedded with thin layers of biotite gneiss or sometimes a little limestone.
3 Other gneisses, chiefly gray feldspar-garnet or dark gray biotite-garnet-feldspar or white feldspar-gneiss. Occasionally a little limestone, quartzite, or hornblende-gneiss may occur closely associated, especially where the glacial drift is heavy.

The largest area of Grenville occupies the western portion of the quadrangle and by far the greater part of it consists of limestone and its associated hornblende gneisses. A considerable area of quartzite lies south of Sodom and a smaller one east of Little mountain. The only distinct area of mica-feldspar gneiss covers a few square miles south of Thurman.

Toward the southeast occur two irregular shaped areas of Grenville which are almost entirely made up of limestone and associated hornblende-garnet gneiss, the limestone being especially thick and well shown in outcrops just west of the Potter-Birch mountain ridge.

The large and very irregular shaped area along the eastern side of the sheet consists mostly of various gneisses with one considerable area of quartzite south of Pottersville and another east of Chase mountain. The only mappable limestone belt there is a small one extending eastward from Valentine pond.

A patch of Grenville gneiss lies at the extreme northwestern corner of the sheet and another at the northeastern corner, while a belt of limestone just enters the northern map limit at the Natural Bridge. The Grenville around Loon lake consists mostly of white to gray gneisses.

A number of small patches of Grenville are shown within the igneous rock areas and these usually represent actual inclusions of the Grenville which are large enough to be indicated on the map. No attempt has been made to show the many smaller inclusions. The Grenville occurring within the areas of mixed gneisses will be discussed in connection with those gneisses.

Grenville types. The Grenville types are described in considerable detail because, in the writer's opinion, if the broader structural and stratigraphic relations of the Grenville series are ever to be worked out, it is necessary to have these rocks carefully descriped and mapped over a much larger area than that of a single quadrangle. When a number of the other quadrangles of the southeastern Adirondacks, in addition to those of Broadalbin, Saratoga, and North Creek already published and the Lake Pleasant now being studied, are mapped in detail, it is quite possible that some of the larger structural and stratigraphic features may be made out.

Crystalline limestone. In common with the Newcomb and the southern portion of the Schroon lake sheets, the limestone of the North Creek sheet is much more prominently developed than is usual in the southeastern Adirondacks. The numerous outcrops of limestone (actually observed) are indicated on the accompanying map.

Perhaps the most abundant variety is a nearly white, medium to coarse crystalline, very calcitic limestone through which are scattered numerous flakes of graphite and phlogopite or biotite and occasional specks of pyrrhotite. The calcite crystals range from a few millimeters to more than a half inch across, while the graphite flakes are commonly several millimeters across. Other crystals less often seen in this rock are pyrite, nearly colorless pyroxene, and brown tourmaline. Rarely the limestone is rather dolomitic. This variety of limestone appears in many excellent exposures, the most extensive outcrops perhaps being on the small hill just south of Daggett pond.

A second very common variety is nearly white, medium to coarse-grained calcitic and with numerous irregular shaped, pellucid quartz grains, flakes of graphite, and specks of pyrite or

Plate 1

Courtesy Moore & Gibson Co., New York

View of the Natural Bridge on Trout brook, 2 miles northwest of Pottersville. During the season of low water all the water flows under the arch here shown. The rock is banded, Grenville, crystalline limestone.

pyrrhotite scattered through the mass. The quartz grains usually range in size up to five or six millimeters and stand out as pale straw yellow or clear masses in very bold relief upon the weathered surfaces. Tiny garnet and green pyroxene crystals are rarely present. This variety is also widely distributed and among many other good outcrops are: just east of North Creek; at the Natural Bridge; just south of Crane mountain; and 1½ miles due north of Warrensburg.

A third variety which is rather widely distributed though not so common as those above described may be called serpentine limestone or green marble. One kind of this rock is medium-grained, nearly white, crystalline limestone but with many large blotches or irregular streaks of dark to light olive green serpentine scattered through it. A second kind has scattered through it numerous specks of serpentine or small pale green serpentinized pyroxenes. Different names have been applied to this green marble which has been briefly described by G. P. Merrill who says[1]: "The serpentine in the Warren county Ophiolite, Ophicalcite or Verdantique as it has been variously called, is an alteration or metasomatic product after a mineral of the pyroxene group. The original rock would appear to have been simply a pyroxenic limestone, the pyroxene occurring either in scattering granules or in granular aggregates of considerable size." Among other places this green marble is well shown in the quarries one-half of a mile southwest and three-fourths of a mile southeast of Thurman village, and in the prospect hole at the western base of Hackensack mountain.

Pure white tremolite crystals are sometimes closely associated with the limestone as in many outcrops about a mile east of Little mountain pond. One and one-half miles due north of Warrensburg irregular streaks or veins of tremolite, quartz, pyroxene, and titanite are closely involved with the limestone. The tremolite crystals are up to two inches long and the green pyroxenes up to one-quarter of an inch and perfectly formed.

Asbestos veins sometimes occur in the serpentine marble, these being best shown at the asbestos mine three-quarters of a mile southeast of Thurman where numerous veins attain a width up to three-quarters of an inch.

Green pyroxene or rusty biotite gneisses are sometimes involved in the contorted limestone in the form of streaks or inclusions which have been drawn out or broken by the pressure. See figure 9 and plate 12.

[1] Amer. Jour. Sci., Mar. 1889, p. 191.

A hand specimen, from the prospect hole 2½ miles south of Pottersville, is a very coarse-grained mass of calcite, brown hornblende, and graphite through which are scattered small flakes or crystals of phlogopite, pyrite, and pyroxene (mostly serpentinized). The hornblende and calcite crystals are as much as an inch across.

Quartzite. In the quartzite areas shown on the map south of Sodom, south of Pottersville, and east of Chase mountain, the rock consists almost wholly of distinctly bedded, pure quartzite (with layers up to 1½ feet thick) interstratified with thin layers of biotite-quartz gneiss.

The quartzite of the area southwest of Thurman contains many closely involved tremolite and limestone beds.

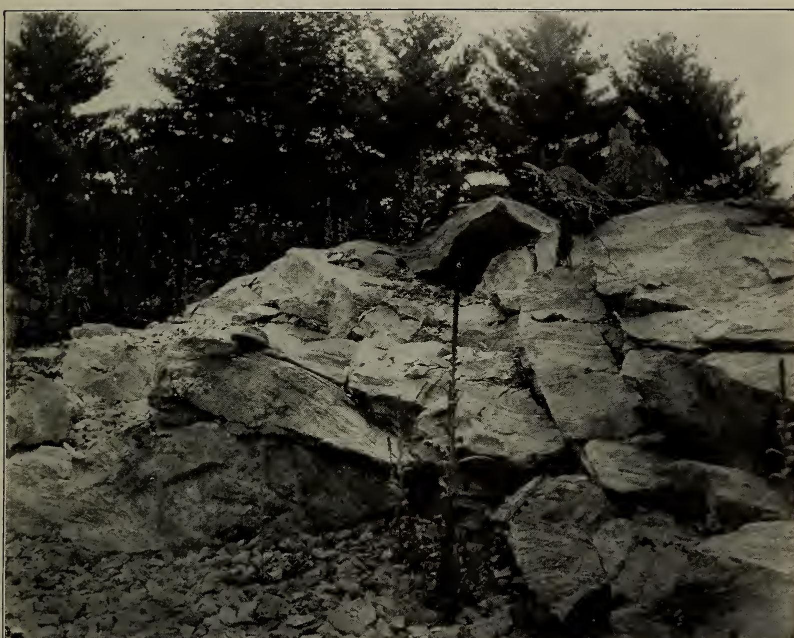
Thin layers of quartzite are occasionally present in the other Grenville areas but these are usually rather impure containing more or less feldspar, biotite, muscovite or graphite.

Hornblende-garnet-feldspar gneisses. Of the two principal facies of these gneisses, one is a gray, medium to fairly coarse-grained hornblende-feldspar gneiss in which are embedded occasional large brownish red garnets of the almandite type. The feldspars comprise both orthoclase and plagioclase and the hornblende is very dark green to nearly black. Biotite, magnetite, and pyrite generally occur in small amounts. The garnets never show crystal form but are always more or less rounded and highly fractured. These garnets commonly range in size from one to five inches and are often surrounded by rims or envelops of pure hornblende crystals. Fine specimens of such garnets, surrounded by rims of hornblende and embedded in the gray matrix, may be obtained at the old garnet mines near the top of Oven mountain and south of Holcombville.

Another facies is fine to medium-grained, darker gray (with reddish tinge), less feldspathic, and more garnetiferous but with the reddish brown garnets all very small and rather evenly scattered through the rock. Small amounts of magnetite, quartz, and pyrite are also usually present.

These hornblende-garnet-feldspar gneisses are almost invariably closely associated with the limestone beds, the two rocks often appearing in a single outcrop. Numerous fine exposures may be seen along the south and west sides of Crane mountain, 1 mile west of Pine mountain, just northwest of No. 9 mountain, and 1 mile east of Cherry ridge.

Plate 2



W. J. Miller, photo

Grenville light gray, very quartzose gneiss, as seen in the quarry near the southeastern end of Loon lake. The banded and jointed character of the rock is well shown.

Feldspar-biotite-garnet gneisses There are a number of rather distinct facies of these gneisses which show all sorts of gradations from one to another. One common facies is a fine to medium-grained gneiss in dark gray and nearly white alternating bands. The biotite is wholly confined to the dark layers, while small scattering garnets appear in both. Such rock is common in the gneiss areas, being especially abundant on the mountain side east and south of Valentine pond and northeast of Fuller pond.

Another facies is medium to coarse-grained and not so perfectly banded. It is best shown in the small mountain 1½ miles north of Valentine pond.

A third facies is a fine to rather coarse-grained, gray to dark gray rock, clearly gneissoid, usually banded and with numerous pink to amethyst garnets up to five millimeters across. Such rocks are very common in the Grenville gneiss areas as, for example, in the quarry near the southeastern end of Loon lake and at the western base of Prospect mountain.

Hornblende-feldspar gneiss. The most common facies of these rocks is a fine to medium-grained, dark gray gneiss almost wholly devoid of garnets. It is very gneissoid and amphibolite-like but not at all banded. It is closely associated with limestone, sometimes with thin layers of that rock interbedded. The whole ridge extending for five miles southeastward from North Creek is practically made up of this rock.

Another but similar looking gneiss contains orthoclase, plagioclase, hornblende, and hypersthene together with small amounts of magnetite and graphite. This is a much more locally developed gneiss as, for example, immediately under the limestone at the Natural Bridge.

Feldspar-quartz gneisses. These are the white or very light gray gneisses of the district. Perhaps the most typical examples are found in excellent exposures along the road near the quarry at the southeastern end of Loon lake. This is a fine to medium grained, very light gray gneiss with some tiny biotite flakes and small brown garnets scattered through the mass. A slide shows about 80 per cent of orthoclase, microcline, and microperthite in nearly equal amounts; 13 per cent quartz; together with small amounts of plagioclase, biotite and garnet. This light gneiss is in thin to thick beds and repeatedly interbedded with biotite-garnet gneisses. A very similar light gneiss, but with graphite flakes, occurs a mile farther northward along the same road.

Feldspar-quartz light gneisses also occur three-quarters of a mile south of Thurman; at Starbuckville; and one-quarter of a mile north of Chestertown.

Pyroxene gneisses. These gneisses are much less abundant than those above described. The most common facies is a fine to medium-grained intimate mixture of small grains or crystals of green pyroxene and reddish brown garnet, with sometimes one and sometimes the other predominating. Such rocks are well exposed in the Sanders Brothers mine near the mouth of Mill creek, and at the old Parker mine just southwest of Daggett pond.

Another facies is a greenish gray to greenish gneiss which contains more or less feldspar in addition to the small garnets. Such rock makes up the inclusion 1 mile west of The Glen, and also occurs along the road one-quarter of a mile north of the north end of Loon lake. Interbedded with the rock at this last named locality is a schistose orthoclase, green pyroxene, phlogopite rock, with occasional graphite flakes up to 3 or 4 millimeters across.

Sillimanite-feldspar-garnet gneisses. Such rocks were observed at but two localities, namely, three-quarters of a mile west-northwest of Starbuckville and 1 mile south of South Horicon. A thin section and specimen from the large outcrop at the latter place shows the rock to be fairly coarse-grained, gray, moderately gneissoid and made up of a matrix of orthoclase, microperthite, and quartz in which are embedded many pale pink garnets, small prisms of sillimanite, tiny graphite flakes, and some small magnetite and colorless pyroxene crystals. At the first named locality the rock is well banded and contains fibrous sillimanite in irregular streaks and also some biotite.

Graphite schists or gneisses. As we have learned, graphite flakes are common in the limestone and sometimes present in the quartzites and various gneisses. True graphite schists or gneisses are, however, rare, the only ones noted being at the old graphite mine 1 mile southwest of Johnsburg where the rocks are light to dark gray and thin to thick bedded. One specimen is almost a quartzite, but with numerous small biotite and graphite flakes. Another specimen is a feldspar-quartz schistose rock without biotite and fairly filled with graphite flakes generally from 1 to 2 millimeters across. Still another specimen is a feldspar-quartz-biotite gneiss with few graphite flakes.

Grenville stratigraphy. Any attempt to work out the stratigraphy of the Grenville series must of necessity be much more unsatisfactory than if we were dealing with a great thickness of unaltered fossiliferous strata. However, because of the excellence and frequency of the exposures in most of the Grenville areas, some unusually good results have been obtained though it should not be understood that the statements or conclusions here given are always regarded as thoroughly established. Much detailed work on the adjoining areas will have to be carried on before such statements can possibly be made.

So far as can be made out from a study of all the Grenville sections, the order of succession of the strata appears to be:

5 Dark gray biotite-garnet gneiss. Thickness unknown.

4 Dark hornblende gneiss. Thickness at least 2000 feet.

3 Crystalline limestone. Thickness of some 10,000 or 12,000 feet, but frequently interbedded with more or less hornblende or pyroxene gneisses or quartzite.

2 Quartzite. Thickness of about 3000 feet and generally pure except for very thin layers of biotite gneiss.

1 Gray, banded biotite-garnet gneiss. Thickness unknown.

Some Grenville rocks which are more locally well developed are not included in the above list because their stratigraphic positions are wholly unknown. Among such rocks are the graphite schist, the white gneiss, and the sillimanite gneiss.

The best extensive section within the quadrangle is shown by figure 1 which represents the succession of strata along a northeast-southwest line through the Grenville area between Oven mountain and Wevertown. The position of the section is indicated by the line EE on the geologic map. This is by no means a perfectly continuous section, but the outcrops are numerous enough so that the condition of things shown in the figure can not be far wrong. A total of from 18,000 to 20,000 feet of Grenville strata appears to be shown in this section. The dip and strike of the strata are pretty constant the whole length of the section, and though the Oven mountain fault probably passes across the section it is not thought materially to affect the position and thickness of the strata. The hornblende gneiss toward the top of the section forms the prominent ridge which extends northward to the Hudson river.

Figure 2 represents an east-west section across the valley one-third of a mile south of Daggett pond where there is an almost unbroken succession of nearly pure limestone whose total thickness is something like 3000 feet. On the west side, and dipping under the limestone, are some beds of hornblende-garnet gneiss.

This limestone appears to correspond with the lower part of the limestone mass in figure 1.

There is no positive proof that the quartzite shown in figure 3 is the same as that of the lower part of figure 1, but the two rock masses are of much the same character and both are of great thickness. This quartzite of figure 3, which represents a section across the valley between Chase and Bull Rock mountains, is nearly pure and shows a thickness of about 3000 feet with banded biotite-garnet gneiss dipping under it on the west side.

Figure 4 is another fine section of the quartzite which also shows the underlying rock to be a banded biotite-garnet gneiss of unknown thickness.

The limestone of the Valentine pond valley appears to dip southward under a thick belt of distinctly light and dark banded garnet gneisses, but just where these rocks belong in the columnar section can not be said.

The quartzite in the area southwest of Thurman is often very tremolitic, which suggests that it does not belong with the other quartzites of the quadrangle.

QUARTZ SYENITE

As shown on the geologic map, the syenite covers about two-ninths of the area of the quadrangle and is distributed in very irregular shaped areas. Boundary lines between the syenite and granite can not be sharply drawn because of the gradation of the one rock into the other. Against the Grenville the boundary is generally not very sharp except where the Grenville has been faulted against the syenite.

As regards granularity, structure and mineral composition the syenite is a very variable rock. The granularity ranges from fine to fairly coarse grain, with medium grain decidedly prevalent and with only rarely suggestions of a porphyritic texture. Evidence of crushing or granulation of the rock is common, especially in the cases of the more acid (granitic) syenites where the feldspars more than the other minerals are granulated. In structure the rock ranges from only faintly gneissoid to very clearly gneissoid, which is due to the arrangement of the dark colored minerals with axes parallel to the direction of foliation. All facies of the syenite are quartzose and the range in mineral composition is from pyroxene-quartz-syenite to granitic hornblende syenite as shown in table 1.[1]

[1] In this and the succeeding tables only close approximation to the volumetric proportions of minerals present is intended.

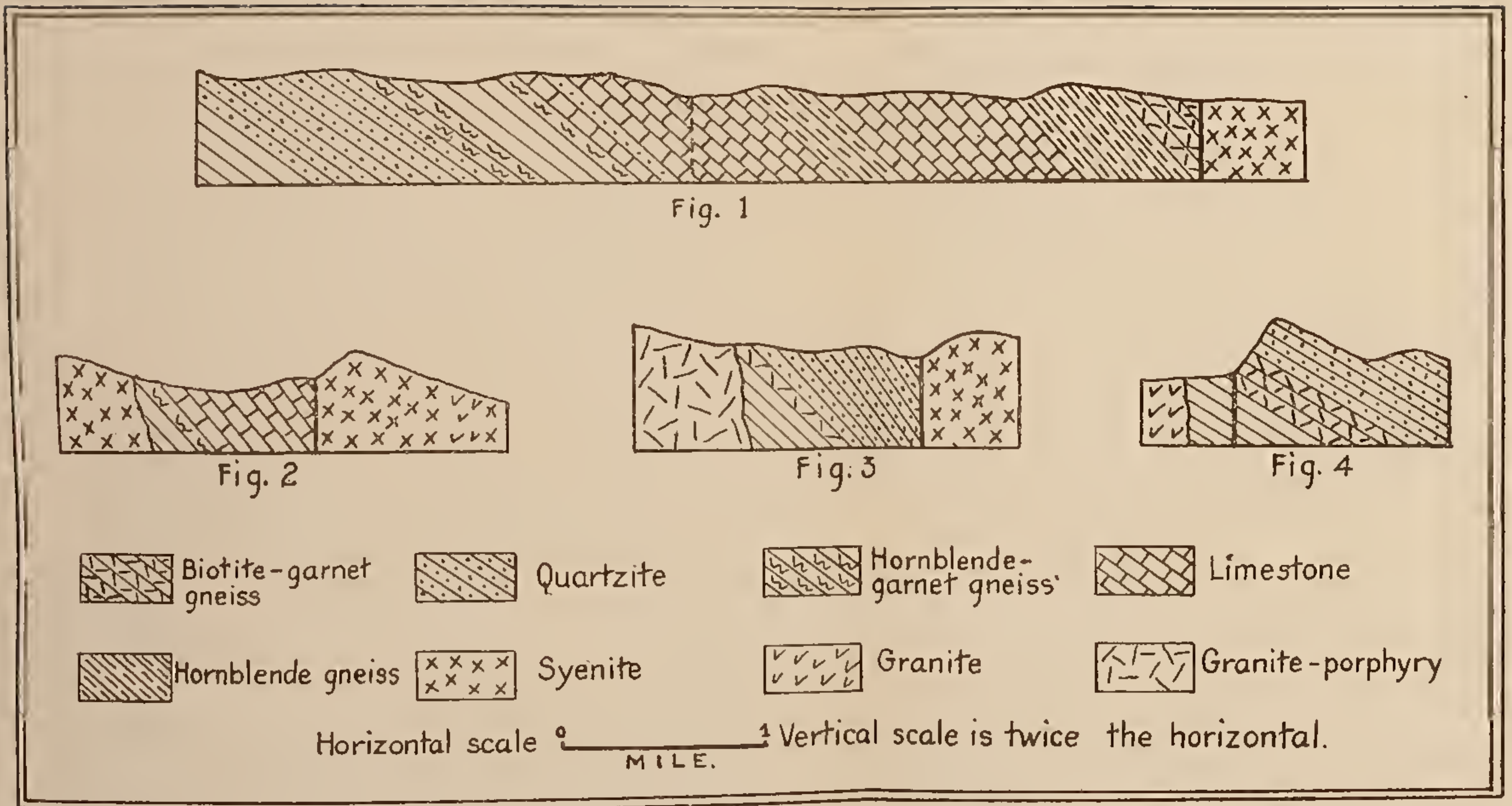


Fig. 1. Northeast-southwest section through the Grenville area which lies between Oven and Mill mountains. The exact position of the section is indicated on the geological map

Fig. 2. Section along an east-west line through the Grenville one-third of a mile south of Daggett pond

Fig. 3. Northeast-southwest section from the summit of the southern spur of Bull Rock mountain to the summit of Chase mountain and through the belt of Grenville quartzite

Fig. 4. Northeast-southwest section through the summit of Loon Lake mountain

TABLE I

Pyroxene syenite

	No. of slide	Orthoclase	Microperthite	Microcline	Plagioclase	Quartz	Hornblende	Biotite	Monoclinic pyroxene	Magnetite	Zoisite	Apatite	Zircon	Pyrite	Titanite
1	17	25	....	....	Ol-Lab 55	12	....	5	25	2	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	.....	..
2	13	15	25	15	Ol 14	18	1	....	10	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	.....	..
3	14	25	25	....	Ol 5	20	8	....	15	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	little	..
					Granitic hornblende syenite										
4	15	25	25	....	Ol 6	22	18	2	....	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	.....	..
5	34	5	50	....	Ol 5	24	12	....	....	2	1	$\frac{1}{4}$	$\frac{1}{4}$	.....	$\frac{1}{2}$
6	12	10	35	2	Ol 12	25	14	....	....	1	$\frac{1}{2}$	little	$\frac{1}{2}$	.....	..
7	16	5	65	....	Ol 3	25	$\frac{1}{2}$	$\frac{1}{2}$	....	$\frac{1}{2}$	$\frac{1}{2}$	.....	little	.....	..

The color of the fresh rock is the usual greenish gray of the Adirondack syenites, while the weathered surfaces are of yellowish brown to brown color. Because of vigorous glaciation even the weathered surfaces are hard, decomposed rock seldom being seen except in a few protected places on the south sides of mountains. Below this weathered surface it is usually not more than a few inches to the fresh greenish gray rock.

That the syenite has been intruded into the Grenville is abundantly proved by the many inclusions of all sorts of Grenville rocks, but most of these are too small to be represented on the geologic map. Some of the best examples of Grenville inclusions are to be found in the mixed gneiss areas which will be described below.

Pyroxene syenite. This syenite represents the most basic facies of the great syenite-granite intrusive mass. The generally faint development of gneissoid structure, low quartz and hornblende contents, and the presence of pyroxene are the chief differences between this and the granitic hornblende syenite. The range in composition is well brought out in table 1 which represents thin sections of carefully selected samples. The pyroxene is seen to be the most characteristic mineral of the rock. This pyroxene is of a beautiful green color, clearly monoclinic, and shows good cleavages.

Crystal outlines are sometimes distinct. Professor Kemp has noted a similar pyroxene in the syenite of the Elizabethtown-Port Henry quadrangles and he suggests the presence of the jadeite molecule in its composition. Garnets seldom occur in this syenite.

The most basic rock of all is shown by no. 1 of the table. This rock makes up the Bull Rock mountain mass. It is unusually high in plagioclase, pyroxene, and biotite and low in quartz, and is nearer the gabbro in appearance and composition than any other rock of the whole region. It is fine to medium grained and of rather a bluish gray than greenish gray color when fresh.

Numbers 2 and 3 of the table are from the mountain 2 miles south-southeast of Riverside, and from along the road 1 mile west-southwest of Daggett pond respectively. In the field it is generally impossible to distinguish this pyroxene syenite from much of the granitic hornblende syenite and this, together with the fact that the two rocks grade perfectly into each other, renders separate mapping practically impossible. The pyroxene syenite, however, is certainly less common than the hornblende syenite.

Granitic hornblende syenite. The range in mineral composition of this rock is shown by the selected examples given in table 1. Microperthite and orthoclase are always present though in very variable amounts, while the quartz and hornblende contents are high and biotite is scarcely represented. In addition to the minerals shown in the table a few scattering garnets sometimes occur. No. 7, with its almost total lack of hornblende, is an unusual type. The gneissic structure is usually well developed though at times it becomes very faint. This granitic syenite on the one hand grades perfectly into the pyroxene syenite and on the other into the granites below described. Arbitrarily, when the quartz content passes beyond 25 per cent, the rock is classed as granite and, as nearly as possible, the rocks have been separately mapped on this basis. The very common presence of biotite in the granite has also been a help in mapping.

Numbers 4, 5, 6, and 7 are respectively from Potter mountain, 1½ miles east of Pottersville, one-third of a mile north of the north end of Loon lake, and the summit of Little mountain.

GRANITE

As already stated, the granitic syenite passes through perfect gradations into the granite and these rocks are very clearly only different phases of the same great intrusive body. The rock is rather arbitrarily called granite when it contains more than 25 per cent of quartz. By becoming coarse-grained and porphyritic it also passes gradually into the granite porphyry. As in the case of the syenite, the contact against the Grenville is seldom sharp except along the lines of faulting. The area covered by the granite is almost the same as that of the syenite or about two-ninths of the quadrangle.

This rock, too, is decidedly variable as regards color, granularity, structure and mineral composition. The colors range through greenish gray, light gray, and pinkish to almost red. These color varieties are especially well shown in the vicinity of The Glen. Pinkish granites are the most abundant.

The granularity of the rocks varies from fine to coarse grain, with a medium grain predominating. Coarse-grained types often show a tendency toward porphyritic texture and thus approach the granite porphyry. The granites are almost always highly granulated, especially the more gneissoid varieties in which the feldspars are most badly crushed. There is a wide range from poorly gneissoid rocks to those which are highly foliated and almost banded, the latter being particularly true of the commonly occurring pink granites.

The range in mineral composition is well illustrated by the selected examples given in table 2. As compared with the granitic syenite, the chief differences are the high quartz content, the common occurrence of microcline, the generally lower content of hornblende, and the almost constant presence of biotite.

TABLE 2

Granite

	No. of slide	Orthoclase	Microperthite	Microcline	Plagioclase	Quartz	Hornblende	Biotite	Zoisite	Garnet	Zircon	Magnetite	Apatite
1	21	22	22	....	Ol 7	26	20	2	....	....	little	1	......
2	35	7	30	18	Ol 3	28	8	1	½	3	¼	1	¼
3	18	17	50	....	....	30	....	2	....	....	little	1	......
4	53	10	45	4	Ol-And 5	30	5	....	....	½	¼	¼	......
5	32	5	40	....	Ol-And 10	35	7	1	½	....	½	1	little
6	31	10	18	14	Ol 10	35	6	2	1	1	½	2	½

Number 1 is a fine example of a transition rock from a granitic syenite to granite as seen along the river in big ledges one-half of a mile south of The Glen. The color of the rock is pinkish gray. Especially noteworthy are the comparatively low quartz and high hornblende contents, and the absence of microcline.

Number 3 is typical looking pink, biotite granite from the granite ridge just west of Crane mountain.

Number 6 is a very quartzose, hornblende, biotite, pink granite with considerable microcline as seen in excellent outcrops along the road 1½ miles south of Riverside.

Only a few of the observed masses of Grenville or mixed gneisses which occur within the granite are large enough to be shown on the geologic map. Small inclusions or stringers, sometimes sharply outlined and sometimes seeming to grade into the granite, are very numerous. Only a few examples will be cited. Thus, a large, homogeneous mass of very typical granite, one-quarter of a mile above the mouth of Glen brook, contains a number of clear-cut Grenville hornblende gneiss inclusions. These inclusions are mostly long (10 to 20 feet), narrow stringers which are drawn out parallel to the foliation of the granite. Similar inclusions are common 1 mile south of The Glen along the east bank of the river, and in the Mill mountain mass. On the west bank of the Hudson river and just opposite the Ferry (east of Heath mountain) a ledge of coarse-grained hornblende granite contains ten or fifteen fine examples of small (none over 3 feet long) very angular inclusions of Grenville hornblende gneiss.

Features of special interest in connection with the granites are the frequent and comparatively sudden transitions from the gray to pink varieties, and from the more syenitic or basic facies to the more truly granitic facies. The effect is to give wide bands or layers of varying color and composition and yet all clearly belonging to the same rock mass because of the true gradation of one layer or band into another. Among many places where such phenomena have been observed are in the vicinity of The Glen, and along the road one-half of a mile north of the north end of Loon lake. The writer has already described similar occurrences in the region of the Port Leyden quadrangle.[1] Professor Kemp, in the bulletin on the Elizabethtown-Port Henry region, has recently described and suggested an explanation for similar but even more extreme phenomena as follows: "The most acidic variety will quite sharply replace it [the syenite]; and in the same way a

[1] N. Y. State Mus. Bul. 135, p. 16–17.

very basic variety may come in and constitute the section for 50 or 100 feet or more. Yet, while the transition is sharp, there is no evidence of separate intrusive masses nor is one justified in inferring more than a differentiation of an eruptive mass into layers or portions of contrasted composition. . . . That this differentiation takes place in magmas is one of the growing convictions of students of igneous rocks." [1] Now, so far as the writer's observations in the North Creek region are concerned, they fully accord with Professor Kemp's interpretation of this puzzling phenomenon. Of course, the rocks have been severely compressed and possibly folded and the banded effect may thus have been accentuated, but nevertheless there appears to be no getting away from the apparent fact of some sort of differentiation of the granitic magma into layers of varying composition.

GRANITE PORPHYRY

This rock represents another phase of the great syenite-granite intrusive mass and always shows a perfect gradation into either the granite or syenite, so that sharp lines of separation between these rock types can not be drawn. On the accompanying geologic map this rock is seen to be rather widely distributed in small to large irregular shaped areas making up altogether perhaps a little less than one-ninth of the area of the quadrangle. A very similar rock occurring in the vicinity of Northville has recently been described by the writer [2] and that description applies almost perfectly to the North Creek granite porphyry. Exactly the same evidences which were presented to prove that the Northville granite porphyry is really only a facies or differentiation product of the great syenite magma, may also be applied to this granite porphyry. Still more recently such rock has been found by the writer in the northern portion of the Lake Pleasant quadrangle. Thus it is quite certain that granite porphyry is a rather widespread rock in the southeastern Adirondacks.

The typical rock is gray to pinkish gray, thoroughly gneissoid, and with beautifully developed porphyritic texture. The phenocrysts of feldspar are usually from one-half to one inch long and more or less flattened parallel to the foliation. Carlsbad twins are often easily recognizable. Feldspar, quartz, and biotite or hornblende are always plainly visible to the naked eye. Often large

[1] N. Y. State Mus. Bul. 138, p. 48 and 128.
[2] N. Y. State Mus. Bul. 153, p. 17-20.

quartz crystals are also decidedly flattened parallel to the foliation. The phenocrysts are embedded in a fine to medium-grained matrix of feldspar, quartz, and biotite or hornblende. The rock nearly always shows the effects of dynamic metamorphism, the more or less crushed and granulated feldspars generally being clearly visible to the naked eye. The degree of foliation often varies considerably from place to place, and the porphyritic texture, especially along the borders, becomes notably less prominent.

The general range in mineral composition is shown by the examples given in table 3.

TABLE 3

Granite porphyry

	No. of slide	Orthoclase	Microperthite	Microcline	Plagioclase	Quartz	Hornblende	Biotite	Magnetite	Zircon	Zoisite	Apatite	Garnet
1	25	10	10	25	Ol-And 1	44	4	4	....	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	1
2	26	10	10	25	Ol-And 5	30	10	....	1	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	8
3	27	15	20	20	....	30	8	....	1	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	5
4	28	8	35	8	Ol-And 7	30	....	10	1	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	......

Number 1 is a very typical looking granite porphyry from the quarry at Horicon. This is the rock which Professor Kemp described as the "Horicon gneiss" some years ago.[1]

Number 2 is from Kelm mountain; no. 3 from one mile south of Kelm mountain; and no. 4 from the south base of Prospect mountain.

A good example of a rather coarse, somewhat porphyritic, pink granite which might almost pass for a granite porphyry occurs in the quarry along the road 2 miles northeast of Pottersville.

It so happened that no Grenville masses within the granite porphyry were of sufficient size to be indicated on the geologic map, but in the field one may see a good many small patches or streaks of Grenville gneiss sometimes as clear-cut inclusions and at other times seemingly more or less fused into the granite, thus giving very locally a sort of mixed gneiss effect.

[1] 17th Annual Rep't N. Y. State Geol. 1897, p. 510, 541.

MIXED GNEISSES

In the areas mapped as mixed gneisses, the rocks are more or less intimate associations of the various Grenville, syenite, granite, and granite porphyry gneisses. They are really areas of Grenville which have been all cut to pieces, and in some cases apparently partially fused, by the great igneous intrusives. In some areas true Grenville rocks predominate; in others true igneous rocks prevail; while in still others the most common rock appears to be of intermediate character due to an actual melting and incorporation of Grenville sediments by the molten intrusions. Except along fault lines, these mixed rocks everywhere grade into either true Grenville or syenite or granite and the drawing of boundary lines is largely a matter of personal judgment. Any attempt to separate the various members of these mixed gneiss areas would be unsatisfactory because of the general insufficiency of outcrops and the small scale of the map.

There are many places within the quadrangle where, as a result of more or less perfect assimilation, rocks of intermediate composition occur on both small and large scales. One and one-third miles northeast of Kelm mountain and near the map edge there are fine illustrations of dark Grenville garnet gneiss inclusions in the granite porphyry, the inclusions usually grading perfectly through zones of a few feet into the granite. The intermediate rock is coarse-grained, very garnetiferous, and not so porphyritic as the true granite porphyry. Similar cases of local assimilation by granite porphyry, granite and syenite have been observed at other places within the quadrangle.

On a large scale, perhaps the best examples of rocks of intermediate character make up most of the mixed gneiss area just east of Chestertown. Thus the whole top of Prospect mountain consists of gray, fine-grained, very massive rock which has the composition of a biotite granite. This rock is quite homogeneous except for occasional patches or stringers of gray Grenville gneisses which are fused into the mass. Passing southward and southwestward down the mountain side, this rock grades perfectly into a medium-grained, gray, biotite granite which contains very few Grenville inclusions, and this rock, in turn, grades perfectly into the typical biotite granite porphyry at the base of the mountain. Passing westward down the mountain side, however, the fine-grained granitic rock at the top gradually becomes coarser grained and contains more numerous and more clearly defined inclusions of Grenville gneisses, with these rocks, in turn, grading into pure biotite-garnet and quartzitic Grenville gneisses at the base of the mountain. Thus we have a perfect transition from the gray, granitic rock into the granite porphyry, on the one hand, and into the Grenville on the other so that there appears to be no escape from the idea that these gray, granitic rocks were formed by actual fusion and incorporation of more or less of the Grenville into the granite porphyry magma. The presence of the inclusions does not necessarily oppose this view because they may well enough simply represent fragments of Grenville which were caught in the granite magma just before consolidation or when the temperature was not high enough actually to melt the fragments. Gray granitic rocks of apparently the same origin are common throughout this mixed gneiss area.

Another interesting mixed gneiss area is the one just north of the village of Horicon. In the vicinity of the quarry, at the base of the mountain, the rock is very typical granite porphyry which contains a few long, narrow, sharply defined, Grenville gneiss inclusions. Going up the mountain side from the quarry, the granite porphyry, which at times (in patches or wide bands) appears typical, is intimately associated with Grenville. This Grenville occurs as large and small inclusions, often sharply defined and nearly always drawn out parallel to the foliation. The included rocks are chiefly banded biotitic, hornblendic, and quartzitic gneisses often in bands from 20 to 30 feet wide. Toward the top of the mountain the rock is mostly like the gray granitic rock already described as occurring at the top of Prospect mountain, and the inclusions are fewer and not so sharply defined. Here again this granitic gneiss appears to be an assimilation product, while farther down the mountain side the temperature seems not to have been high enough to cause any considerable melting or assimilation of the included gneisses.

In the large, mixed gneiss area south of Henderson mountain there are many fine illustrations of very intimately associated Grenville and gray granitic rocks, the Grenville often having been more or less melted into the granites. The granites predominate and some of them at least are thought to be assimilation products. Such phenomena are well exhibited from Igerna southwestward to the river.

In the mixed gneiss area which borders the Chase-Kelm mountain granite porphyry mass on the west, the prevailing rock is a

Plate 3

W. J. Miller, photo

View showing contact between Grenville limestone and granitic syenite as seen from across the Hudson river one-fourth of a mile north of the ferry (southwest of Moon mountain). The smooth ledge at the river's edge on the left and another toward the upper right hand corner are parts of a single mass of syenite mostly concealed by the trees. The other rock is Grenville limestone (white) with numerous closely involved streaks and bands of hornblende (dark) gneiss. The sharp contact between the syenite and Grenville is not well brought out in the picture.

gray, medium-grained, biotitic, granitic gneiss which is intimately associated with some Grenville gneiss. Here again it is quite certain that the granitic gneiss forms a border zone between the granite porphyry and the Grenville, where the former has more or less assimilated some of the latter.

Along the southeastern base of Moon mountain there are excellent exposures of Grenville much cut up by, and often fused into, syenite.

The mixed gneiss area at the southwestern corner of the map affords many fine examples of syenite or granite and Grenville closely involved and fused together. There are also many well-defined inclusions or stringers of Grenville scattered through the igenous rock. These phenomena are especially well shown on Wolf Pond mountain.

The mixed gneiss area which surrounds Heath mountain consists very largely of Grenville gneisses and limestones through which numerous small masses of syenite or granite have been intruded. The most interesting exposures occur along the river for nearly a mile northward from the Ferry. About 1 mile north of the Ferry and on the east side of the river, are great ledges of Grenville limestone and hornblende gneiss, these rocks being badly contorted and broken and containing some patches of good syenite, 10 to 30 feet across, and completely surrounded by either hornblende gneiss or marble. At the same locality a large mass of syenite overlies crystalline limestone and shows the actual sharp contact for fully 100 feet, there being no particular contact phenomena (see plate 3).

About one-half of a mile north of the Ferry, and along the road, there are several very interesting inclusions of Grenville limestone in the syenite. Two of these inclusions (one being 3 or 4 feet across and the other 20 feet long and 2 to 4 feet wide) are completely surrounded by, and in very sharp contact with, the syenite. The limestone is coarse, crystalline, calcitic, and contains graphite. At the contacts small green pyroxene crystals are often common.

The small area near Daggett pond is of interest because the Grenville is there interbanded with granitic syenite, the bands of each rock often being 20 to 40 feet wide and the contacts pretty sharp. One Grenville band is a garnet, pyroxene gneiss, while others are biotite or hornblende gneisses.

The area of mixed gneisses lying to the east of Stockton and Gage mountains shows numerous exposures of closely associated syenite or granite and Grenville gneisses in about equal amounts. There are few suggestions of assimilation, the igneous and sedimentary rocks generally retaining their characteristic features.

The other mixed gneiss areas require no special mention.

THE GABBRO AND ITS DERIVATIVES

Because of the large number of exposures, mode of occurrence, excellent outcrops, frequent contacts against the country rocks, and the remarkable variations in composition and appearance the gabbros are of unusual interest and will be described in considerable detail.

Mode of occurrence

The gabbro and its derivatives nearly always occur in the form of small stocks or bosses rather than as true dikes, their length ranging from 30 to 40 feet to about a mile, and with widths up to three-fourths of a mile. Sixty-one separate gabbro bodies were found and are shown on the geologic map. In spite of the detailed field work a few others have probably escaped the writer's notice.

The ground plan, as represented on the geologic map, is almost invariably elliptical, though sometimes approaching the circular. When the contact with the country rock is carefully traced out it is commonly found to be sharp and shows smooth or flowing outlines against the country rock. In only two or three cases do the gabbro masses approach the true dikelike form, and in each of these cases fine-grained tongues were found to extend into the surrounding rock. One stock, one and one-third miles southeast of Chestertown, shows several such tongues, one of them (1 to 6 inches wide) clearly cutting the granite porphyry for 30 feet. Other and smaller gabbro dikes at the summit of Hackensack mountain, and 1 mile south of South Horicon show a number of such fine-grained tongues.

At one place in the dike or boss which crosses the road 1¼ miles a little west of south of South Horicon, fairly coarse-grained gabbro is in sharp contact (for 6 or 8 feet) with fine-grained gabbro, the latter becoming coarser grained again away from the contact. This suggests a second intrusion of the gabbro after the first but after the first had cooled.

It is a striking fact that in spite of many excellent contacts which were observed, such dikelike tongues are so rare. As Harker says[1]: "Although most of the bodies of granite and other plutonic rocks

[1] Natural History of Igneous Rocks, 1909. p 86.

which have been loosely described as bosses, and so rendered in ideal sections, are doubtless of laccolitic or other stratiform shape; some, not of the largest dimensions, appear to have a pluglike form, with more or less vertical boundaries." The small stocks or bosses of the North Creek region are certainly of this pluglike or pipelike form as shown by the very character of their eroded cross-sections and also by the vertical contacts with the country rock. Among the many fine contacts which came under the writer's observation, not a single exception to the rule of vertical or practically vertical contacts was noted.

In most cases the long axes of the stocks lie parallel to the foliation of the inclosing rock, though there are some notable exceptions. It would therefore seem that the molten intrusives generally followed the lines of least resistance but, even in these cases, the broad ends of the stocks cut sharply across the foliation bands, sometimes for a distance of several hundred yards. Such a phenomenon is well exhibited at the south end of the large stock just south of Mountain Spring lake where a big quarry has been opened up along the contact.

The gabbro stocks are not at all uniformly distributed over the area of the quadrangle, the largest number being confined to a nearly north-south belt with a width of from 3 to 5 miles and extending through the middle of the quadrangle. This belt roughly corresponds to the general strike of the foliation. A secondary belt, about 1 mile wide and 5 miles long near the middle eastern boundary of the sheet, contains a dozen small stocks. With a single small exception the whole western side of the quadrangle is devoid of gabbro masses. In the northeastern portion a few stocks occur, but they may really belong to some other belt not yet mapped. Thus we see that the gabbro intrusions were limited to rather well-defined areas or belts.

Among these gabbro stocks four types of occurrence are especially noteworthy as follows: (1) The normal, dark, basic gabbro with diabasic texture and usually homogeneous throughout; (2) gabbro chiefly of the normal type but with irregular patches or masses of lighter colored rocks of syenitic or dioritic make-up, these patches blending with the normal gabbro; (3) the whole stock made up of lighter colored, more acidic rock; and (4) any one of the above types with blocks or inclusions of the country rock. These four types are all primary variations. Examples of the last three types will be given later.

Megascopic features

The gabbro and its derivatives present a truly remarkable number of facies or varieties clearly visible to the naked eye. The coarseness of grain varies from the merest fraction of a millimeter to fully an inch (for example, the stock on the south side of Loon lake). The fine-grained portions are confined to the borders of the stocks or the few branching tongues and were caused by the more rapid chilling of the rock in those positions. Even the finest grained rocks, however, are holocrystalline. As a rule the coarseness of grain increases toward the interior of the masses, though often medium to coarse grained rocks extend to the very contact. The typical or prevailing gabbro shows a medium grain; that is, the grains are from 1 to 5 millimeters across.

The texture varies from coarse to medium to fine-grained granitoid, to medium to coarse-grained diabasic (ophitic). The gabbro from the stock on the south side of Loon lake is an excellent example of diabase texture in which the feldspar laths attain a length of an inch or more. The typical gabbro always exhibits the diabasic texture.

In color, the gabbro and its derivatives range from nearly black through dark to light gray, the darker varieties often showing a slight reddish tinge due to the presence of garnets. The gray rocks all belong to the more acidic (dioritic and syenitic) facies described below. In one case a greenish gray color was noted. The very dark color of the typical gabbro is due to the fact that the feldspars are so charged with tiny black inclusions.

In the typical gabbros the minerals commonly recognizable with the naked eye or hand lens are plagioclase, pyroxene, hornblende, garnet, biotite, and ilmenite, while in addition to these orthoclase and quartz may often be seen in the more acidic phases.

Except for the rather common presence of highly gneissoid to even schistose amphibolite borders, the stocks of typical gabbro are practically devoid of gneissoid structure. Some of the lighter colored, more acidic phases, however, show fairly well-developed foliation.

It is important to note that many of the above described variations may be found within a single stock as, for example, south of Mountain Spring lake. The following statements from Smyth's description of a similar western Adirondack gabbro[1] fittingly apply here: "These [primary] changes in character take place very suddenly, and the different phases are most irregularly distributed,

[1] Amer. Jour. Sci., April 1896, p. 273–74.

Plate 4

W. J. Miller, photo

A typical exposure of gabbro as seen three-fourths of a mile south-southwest of Loon Lake mountain. Note the very irregularly jointed character of the rock and the whitish mass of pegmatite cutting the gabbro in the lower left-hand corner.

seeming to conform to no law. . . . These primary variations in the rock suffice to give considerable diversity to different portions within a limited area, but this diversity is greatly intensified by certain secondary modifications of structure and composition. As a result of the combined effect of primary and secondary variations, it would be easy to collect, within an area of a few square rods, a half dozen or more specimens whose appearance even in thin section would scarcely suggest that they had any connection with one another." Cushing says[1] of the Adirondack gabbros in general that they show much variation, both primary and secondary, from place to place. Both of these investigators proceed to discuss the secondary variations and their causes but, so far as the writer is aware, little or no attention has been given to the causes of the primary variations which will be considered below.

Microscopic features

Mineralogical composition. The following table will serve to show the great range in mineralogical composition of the gabbro and its derivatives. The figures refer to percentages by volume and are meant to be close approximations only.

TABLE 4

Mineralogical composition of the gabbro and its derivatives

	Slide No.	Orthoclase	Plagioclase	Hornblende	Hypersthene	Augite	Diallage	Ilmenite	Pyrite	Biotite	Garnet	Quartz	Zoisite	Zircon	Apatite	Olivine	Titanite
1	45	...	Lab. 50	...	15	...	...	3	.....	9	8	....	....	.....	.....	15	.....
2	6	...	Lab. 50	8	17	...	7	1	little	8	8	....	....	.....	.....	....	.....
3	2	4.5	Ol-Lab. 38	27	12.5	3	...	2.5	1	7	3.5	....	....	.....	little	....	.....
4	46	15	Lab. 30	10	15	...	...	5	.....	5	20	....	....	.....	.....	....	.....
5	42	10	Ol-Lab. 40	25	....	...	23	little	little	1	little	....	....	.....	.....	....	.....
6	47	10	Ol-Lab. 30	25	20	...	10	1	.....	2	2	....	....	.....	.....	....	.....
7	1	5	Ol-Lab. 40	16	25	...	...	1	.....	5	8	....	....	.....	.....	....	.....
8	60	20	Ol-Lab. 40	10	14	...	...	1	1	2	10	1	1	.....	.....	....	.....
9	5	5	Ol-Lab. 45	14	20	...	...	2	1	6	2	....	....	.....	.....	....	.....
10	49	32	Ol-Lab. 10	45	....	...	...	2	little	6	5	....	....	little	.....	....	.....
11	3	32	Ol-And 20	25	....	...	...	5	.....	5	.....	10	1	.....	little	....	little
12	4	15	Ol-Lab. 57	15	....	...	...	2	1	10	.....	....	....	little	.....	....	.....
13	44	50	Ol-Lab. 15	20	....	8	2	little	little	...	1	2	....	little	little	....	.....
14	43	45	Ol-And 15	28	....	2	...	1	little	...	.....	8	....	.....	little	....	.....

Perhaps the most striking feature brought out by this table is the range of rock types, through many intermediate phases, from a very basic olivine norite to quartz-hornblende syenite. Thus, no. 1 is an olivine norite; nos. 2, 3, 4, 6, 7, and 9 are hornblende norites;

[1] N. Y. State Mus. Bul. 95, p. 328.

no. 5 is a hornblende gabbro; no. 8 is a gabbro-diorite; nos. 10, 13, and 14 are hornblende syenites; no. 11 is a monzonite; and no. 12 is a diorite. The large number of minerals — sixteen in all — is also notable. It is also important to note that in the above table, nos. 3 and 4, 7 and 8, 9 and 10, and 11 and 12, respectively, come from single stocks.

The predominating mineral is feldspar which ranges from labradorite alone in some rocks through all stages, to those rocks which are rich in the more acid plagioclases or orthoclase.

Hornblende, generally in considerable amount, occurs in all but one (no. 1) of the rocks. Sometimes it makes up a fourth or more of the whole rock. Much of the hornblende in the more basic rocks, at least, is of secondary origin and forms corrosion rims (below described) around other minerals. Its color varies from green to brown. In one slide many examples of the transition from pyroxene to hornblende are perfectly shown.

Hypersthene, with a single exception (no. 5), is an important constituent of all the more basic types. It is almost always highly granulated and with pleochroism from greenish gray to pale reddish brown.

Augite and diallage of greenish gray color and with good cleavage, are only occasionally present and rarely as important constituents.

Ilmenite is invariably present in amounts up to 5 per cent and often with transition to leucoxene.

Pyrite in small amount seldom fails.

Biotite and garnet of the usual sort, though mostly in tiny flakes or grains, are present in moderate quantity in all but certain of the more acidic facies. The unusually high percentage of garnet in no. 4 is a fine-grained border phase of a stock.

Quartz, in small irregular shaped grains, is wholly confined to the acidic types.

Zoisite, in small stout prisms, sometimes makes up about 1 per cent of the rock.

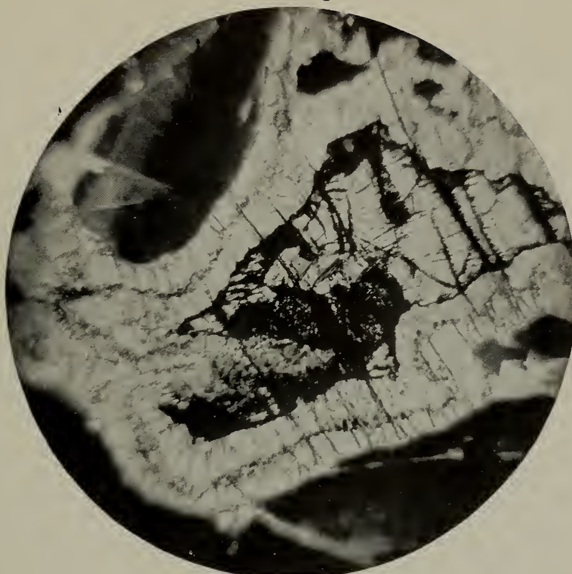
Zircon and apatite, in very small quantities, are almost wholly confined to the acidic facies. The usual absence of the apatite from the typical gabbros is especially noteworthy.

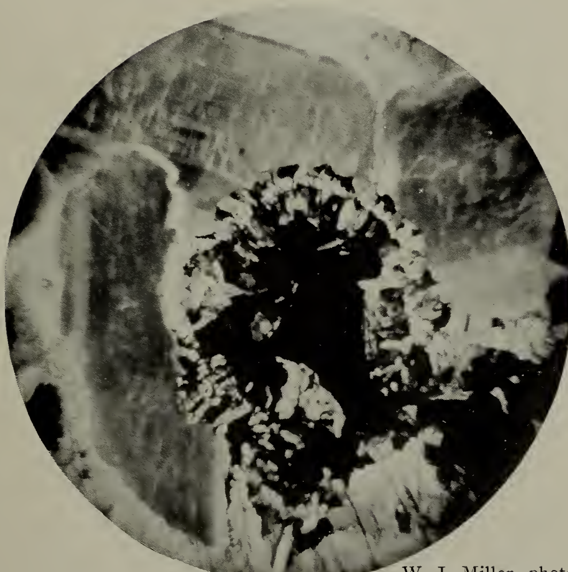
Olivine was noted in but one case (no. 1) and this in the only rock from which hornblende is missing.

Titanite in a few small grains was noted in no. 11.

Reaction or corrosion rims. Reaction or corrosion rims, which are well known in many basic rocks, are exhibited in a truly re-

Plate 5





W. J. Miller, photo

Photomicrographs of thin sections of gabbro from the stock on the south side of Loon lake. Each magnified 15 diameters.

In the upper figure the large central mineral is olivine completely surrounded by successive rims of hypersthene, biotite (narrow and dark), and garnet. Surrounding all are broad laths of labradorite.

In the lower figure the large, black, central mineral is ilmenite, followed by successive rims of biotite, hornblende, garnet and biotite. The second and third — biotite and hornblende — rims are not separable in the photograph. Surrounding all are labradorite crystals.

Plate 6

W. J. Miller, photo

Upper figure. Photomicrograph of thin section of gabbro from the top of Hackensack mountain. Magnified 15 diameters. The central mineral, with good cleavages nearly at right angles, is diallage which is almost completely surrounded by a zone of hornblende (darker colored). As seen under the microscope the rim is very clearly defined. The light gray minerals are basic plagioclase. The diabasic texture of the rock is well shown.

Lower figure. Photomicrograph of a thin section of diabase from the dike one and one-half miles southeast of Johnsburg. Magnified 15 diameters. The long, slender prisms with transverse cracks are augite; the smaller, more numerous, prisms arranged in more or less sheaf like bundles are basic plagioclase; the black areas are glassy groundmass; and the four small, white rounded areas represent quartz, probably of secondary origin.

markable manner in the North Creek region gabbros. In the examples most often described the core is olivine, but in the gabbros here considered the writer has observed cores of olivine, hypersthene, ilmenite, augite, and diallage with from one to five distinct, successive rims surrounding the cores. Professor Kemp has described [1] and figured a number of interesting examples of reaction rims observed in certain gabbros of the eastern Adirondacks.

The following nine types of reaction rims comprise most of those noted by the writer in the North Creek gabbros:

1 Ilmenite surrounded by hornblende.
2 Diallage surrounded by hornblende.
3 Augite surrounded by hornblende.
4 Hypersthene surrounded by garnet.
5 Hypersthene surrounded by successive zones of biotite and hornblende.
6 Olivine with successive zones of hypersthene, hornblende, and garnet.
7 Olivine with successive zones of hypersthene, biotite, and garnet.
8 Hypersthene with successive zones of biotite, feldspar, and garnet.
9 Ilmenite with successive zones of biotite, hornblende, garnet, and biotite.

In nearly all cases the material immediately inclosing the rims is feldspar which, in a sense, adds another zone to each of the above. No. 6 is like one of those described by Kemp. No. 9 is a remarkable example and, because of its additional outer rim of biotite, is even more interesting than a case described by Lacroix.[2] Some of the others may be new examples. The material of each rim appears to be highly granulated or at least made up of numerous small grains. It seems certain that where hypersthene envelops olivine, the former has secondarily developed from the latter. The olivine cores are of very irregular shapes and in all sizes. Where hypersthene forms the core it is probable that all the original olivine has been altered to hypersthene. The common occurrence of hornblende rims around pyroxene strongly suggests the derivation of the former from the latter. Garnet is almost invariably in contact with feldspar which suggests the partial formation, at least, of the garnet from the feldspar.

[1] Geol. Soc. Amer. Bul., 1894, 5:218–21.
[2] Bul. Soc. Min. Fr., 1889, 12:232.

Chemical composition, norm, and mode

Excellent exposures of what is regarded as very typical gabbro occur in the railroad cut 1¼ miles south of The Glen. This rock has been analyzed for the writer by Prof. E. W. Morley.

Table 5

Chemical composition and norm

	Per cent	Mol	Ilm	Ap	Na Cl	Pyr	Orth	Alb	An	Mag	Diop	Hyp	Ol
SiO_2	46.40	.773	...	...	...	...	72	258	168	...	152	69	54
Al_2O_3	14.17	.139	...	...	...	...	12	43	84	...	...	...	...
Fe_2O_3	2.03	.013	...	...	...	...	...	...	...	13	...	...	...
FeO	13.12	.182	38	...	...	2	...	...	...	13	} 76	69	108
MgO	4.94	.124	...	...	...	...	...	...	...	...	}		
CaO	9.65	.172	...	20	...	...	...	...	84	...	68	...	...
Na_2O	3.14	.050	...	...	7	...	...	43	...	...	...	...	...
K_2O	1.12	.012	...	...	...	...	12	...	...	...	...	...	...
H_2O+	.02	...	...	...	...	...	...	...	...	...	...	...	...
H_2O-	.25	...	...	...	...	...	...	...	...	...	...	...	...
TiO_2	3.03	.038	38	...	...	...	...	...	...	...	...	...	...
P_2O_5	.80	.006	...	6	...	...	...	...	...	...	...	...	...
Cl	.15	.004	...	...	15	...	...	...	...	...	...	...	...
MnO	.44	.006	...	...	...	...	...	...	...	...	6	...	...
S	.14	.005	...	...	...	5	...	...	...	...	...	...	...
BaO	.18	.001	...	...	...	...	...	...	...	...	1	...	...
SrO	.10	.001	...	...	...	...	...	...	...	...	1	...	...
F	.04	.002	...	...	...	...	...	...	...	...	...	...	...
ZrO_2	.05	.000	...	...	...	...	...	...	...	...	...	...	...
	99.77												

Orth	6.67	Sal. = 53.37
Alb	22.53	
Anor	23.35	
NaCl	.82	
Ilm	5.78	Fem. = 45.93
Mag	3.02	
Pyr	.24	
Apat	2.02	
Diop	17.53	
Hyper	8.02	
Oliv	9.32	
H_2O+ZrO_2	.32	
	99.62	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{53.37}{45.93} < \frac{5}{3} > \frac{3}{5} =$ III, Salfemane

Order, $\frac{QL}{F} = \frac{.82}{52.55} < \frac{1}{7} =$ 5, Gallare

Rang, $\frac{K_2O^1 + Na_2O^1}{CaO^1} = \frac{62}{84} < \frac{5}{3} > \frac{3}{5} =$ 3, Camptonase

Subrang, $\frac{K_2O^1}{Na_2O^1} = \frac{12}{50} < \frac{3}{5} > \frac{1}{7} =$ 4, Camptonose

TABLE 6

Mode of gabbro

	Units measured	Rel. vols.	S. G.	Units by weight	Percentage weights
Plagioclase.........	2 805	38.09	2.66	7 461	32.72
Orthoclase.........	335	4.55	2.56	858	3.77
Hornblende........	1 990	27.02	3.20	6 368	27.92
Hypersthene........	932	12.65	3.50	3 262	14.30
Biotite.............	505	6.86	3.20	1 616	7.09
Augite.............	227	3.08	3.30	749	3.29
Garnet.............	265	3.59	3.70	980	4.30
Ilmenite...........	184	2.50	5.17	951	4.17
Pyrite.............	95	1.29	5.00	475	2.08
Apatite............	26	.35	3.20	83	.36
	7 364	99.98	....	22 803	100.00

Under the old qualitative system the rock is a hornblende norite, while according to the quantitative system it is a hornblende-camptonose. In thin-section the plagioclase is seen to range from oligoclase to labradorite, and the analysis and mode show that the average composition is that of a basic andesine. The high TiO_2 of the analysis shows either ilmenite or very titaniferous magnetite, the ilmenite being far more probable because of the difficulty of otherwise accounting for such a low content of Fe_2O_3.

TABLE 7

Adirondack gabbro analyses compared

	1	2	3	4	5	6	7
SiO_2	46.40	47.88	47.42	47.16	46.74	44.97	44.77
Al_2O_3	14.17	18.90	17.34	14.45	16.63	15.40	12.46
Fe_2O_3	2.03	1.39	4.91	1.61	2.17	2.29	4.63
FeO	13.12	10.45	10.22	13.81	10.60	12.39	12.99
MgO	4.94	7.10	5.21	5.24	6.11	10.89	5.34
CaO	9.65	8.36	8.09	8.13	8.66	7.50	10.20
Na_2O	3.14	2.75	3.48	3.09	3.81	3.02	2.47
K_2O	1.12	.81	1.89	1.20	.86	.56	.95
H_2O	.27	.61	1.13	.60	.85	.75	.60
CO_2	.....	.12	.....	.35	.07	.23	.37
TiO_2	3.03	1.20	3.60	3.37	2.54	1.18	5.26
P_2O_5	.80	.20	.06	.57	.33	.14	.28
S	.14	.07	.....	.14	.11	.06	.26
MnO	.44	.16	.06	.24	.26	.22	.17
NiOCoO	.....	.02	.....	.02	.03	.02	......
V_2O_5	.....	.....	.....	.....	.....	.02	......
Cl	.15	.....	.21	.....	.....	.....	......
F	.04	.....	.....	.....	.....	.....	......
BaO	.18	.....	.04	.....	.....	.....	......
SrO	.10	.....	.....	.....	.....	.....	......
ZrO_2	.05	.....	.....	.....	.....	.....	......
	99.77	100.02	100.01	99.98	99.77	99.72	100.75

1 One and one-quarter miles south of The Glen, Warren County. E. W. Morley, analyst. Described by W. J. Miller.

2 Split Rock Mine, Westport, Essex county. W. F. Hillebrand, analyst. Described by J. F. Kemp.

3 Dike near Nicholville, St Lawrence county. E. W. Morley, analyst. Described by H. P. Cushing.

4 Woolen Mill, one mile west of Elizabethtown, Essex county. W. F. Hillebrand, analyst. Described by J. F. Kemp.

5 Two miles south of Elizabethtown, Essex county. W. F. Hillebrand, analyst. Described by J. F. Kemp.

6 Same exposure as no. 5. W. F. Hillebrand, analyst. Described by J. F. Kemp.

7 Lincoln Pond, Essex county. George Steiger, analyst. Described by J. F. Kemp.

These analyses show the Adirondack gabbros to be very similar in composition, the only notable variations being in the contents of Al_2O_3, MgO, and TiO_2. The North Creek sheet gabbro (no. 1) agrees most closely with no. 4.

Cause of the primary variations

In attempting to account for the primary variations of these gabbros, the writer believes there is strong evidence favoring the application, to a greater or lesser extent, of Daly's magmatic stoping and assimilation hypothesis to the solution of the problem. For full discussions of this hypothesis the reader is referred to Daly's original papers.[1] Some of the more fundamental principles are as follows: Batholithic (or stock) magmas have reached their present positions chiefly by the successive engulfment of blocks of country rock (xenoliths) stoped or broken out of the roof and walls of the magma chamber; the xenoliths become immersed and dissolved in the depths of the original magma with the formation of a secondary magma; when the magma becomes very viscous (due to cooling) the xenoliths neither sink nor become dissolved.

Only a summary of the application of these principles to the North Creek gabbros will here be given, the writer having more fully discussed this matter in a recent paper.[2]

We have shown that the gabbro stocks are of the pluglike or pipelike form with practically vertical boundaries. Such igneous masses were not intruded by simply displacing or pushing aside the country rock, but rather there was a process of replacement. Thus the mode of occurrence of these stocks furnishes strong evidence in favor of magmatic stoping as an important factor in the intrusion.

The very presence of the inclusions as xenoliths proves that the process of stoping or rifting off blocks from the chamber vault actually did take place to some extent at least, and this when the magma had cooled to a highly viscous condition and hence had comparatively little power to stope and too low a temperature to assimilate the blocks. Thus the occurrence of such xenoliths is quite in harmony with Daly's hypothesis.

The writer believes that the more acidic patches or masses (already described) within the gabbro stocks are evidence of chemical change within the intrusive magma due to solution or partial solution and diffusion of blocks of country rock. In such cases the magma was just hot enough to melt or partially melt and only partially diffuse the blocks of country rock.

Five or six of the stocks are composed wholly of rocks more acidic than the typical gabbro. In the earlier stage of very active intrusion the invading magma was more thoroughly molten and as the blocks of country rock were stoped off they sank in the magma and became thoroughly dissolved and diffused. Since the country rock was nearly always syenite, granite, or gneiss the magma became more and more acidic.

[1] Amer. Jour. Sci. 1903, 15:269–98; Amer. Jour. Sci. 1903, 16:107–26; Amer. Jour. Sci. 1908, 26:17–50.

[2] Jour. of Geol. 1913, 21:160-80.

Contact phenomena

A very interesting case of contact metamorphism produced by the action of the gabbro on granite may be seen at the southern end of the large stock just south of Mountain Spring lake. In a recently opened stone quarry, and about 75 feet higher than the road on its east side, the rocks are laid bare in such a manner that an excellent opportunity is afforded for the study of the contact zones. The following nine zones, passing from the typical gabbro to the typical granite (country rock), have been studied in detail in the field and by means of thin sections and hand specimens.

Zone 1 Typical gabbro well within the gabbro stock. Nearly black, medium grained, and with diabasic texture. (Gradation from 1 to 2)

Zone 2 Syenitic phase of gabbro stock and within a few feet of the granite. Dark gray, medium grained, and with granitoid texture. (Gradation from 2 to 3)

Zone 3 One to three feet wide. Biotite-schist border phase of the gabbro stock. Secondary origin. (Sharp contact between 3 and 4, gabbro and granite)

Zone 4 Four inches wide. Hornblendite phase of the country rock. Nearly black, medium grained, banded parallel to gabbro-granite contact. (Fairly sharp contact between 4 and 5)

Zone 5 Six inches wide. Monzonitic phase of the country rock. Yellowish gray, medium to coarse grained, and banded parallel to the main contact. (Not very sharp contact between 5 and 6)

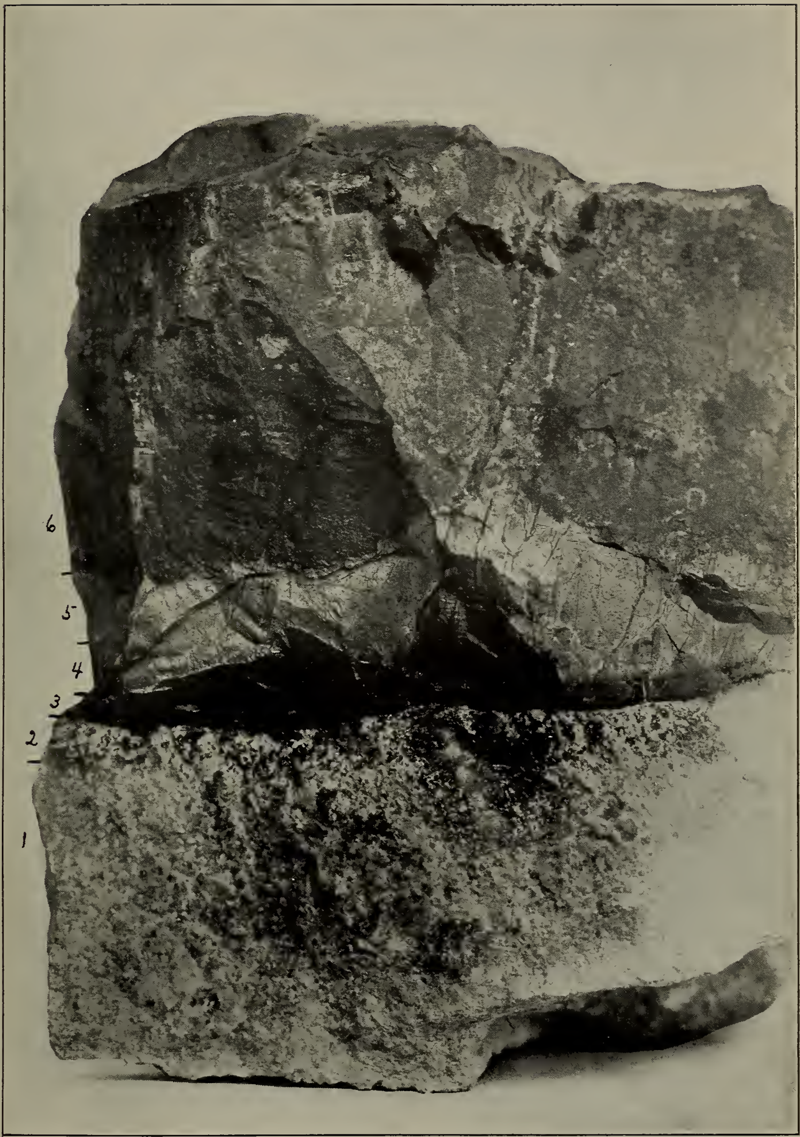
Zone 6 Fifteen to eighteen inches wide. Chiefly hornblendite phase of the country rock but with numerous very narrow streaks of no. 5. Nearly black, medium grained, and banded parallel to the main contact. (Sharp contact between 6 and 7)

Zone 7 Three and one-third feet wide. Monzonitic phase of the country rock like no. 5. Yellowish gray, fairly coarse grained, and banded parallel to the main contact. (Not very sharp contact between 7 and 8)

Zone 8 Seven feet wide. Monzonitic phase of the country rock. Light gray, fairly coarse grained, and not banded. (Gradation from 8 to 9)

Zone 9 Typical (country rock) granite. Pink, medium grained, and very gneissoid but with gneissic bands striking at almost right angles to the main contact.

Plate 7



W. J. Miller, photo

Photograph of a hand specimen showing the contact between diabase and Grenville limestone from the Asbestos mine three-fourths of a mile southeast of Thurman village. Nearly natural size. The zones numbered on the left side correspond to those described on page 43. Zone 4 is scarcely brought out in the picture and zone 3 is best shown on the right side.

TABLE 8

Mineralogical composition of each contact zone

Zone no.	Orthoclase	Microperthite	Microcline	Plagioclase	Hornblende	Hypersthene	Quartz	Biotite	Magnetite	Zircon	Zoisite	Pyrite	Garnet
1	5	....	....	Ol-lab 45	14	20	....	6	2	......	......	1	2
2	32	....	....	Ol-lab 10	45	....	....	6	2	little	......	little	5
3	Biotite-schist with some feldspar												
4	Like No. 6												
5	28	....	....	Ol-and 50	20	....	1	....	$\frac{1}{2}$	little	little	......	....
6	15	....	....	Ol-and 5	72	....	....	....	7	$\frac{1}{2}$	$\frac{1}{2}$	little	
7	Like No. 5												
8	33	....	....	Ol-and 55	10	....	1	....	....	$\frac{1}{2}$	$\frac{1}{2}$	little	
9	40	15	4	Ol-and 5	5	....	30	....	$\frac{1}{2}$	little	......	......	$\frac{1}{2}$

A noteworthy feature is the fact that the strike of the foliation of the very gneissoid country rock is nearly at right angles to the gabbro-granite contact, while the clearly defined contact zones are parallel to the contact.

Other features of special interest are the syenitic border (except for the secondary biotite-schist) of the gabbro near the contact, and the almost complete absence of quartz from the granite within a dozen feet of the main contact. Thus the country rock (granite) is distinctly more basic near the contact, while the gabbro is distinctly more acidic near the contact.

Whether these interesting endomorphic and exomorphic changes are to be accounted for on the basis of assimilation of some of the country rock during the intrusion of the gabbro, or on the basis of the action of vapors from the intrusive, it at least appears quite certain that the gabbro must have been considerably superheated in order to have so notably affected the granite. As judged by the mode of occurrence of the gabbro stock, the stoping hypothesis recently advocated by Daly or the hypothesis of marginal assimilation might be applied to account for the more acidic border phase of the gabbro, but the sharp contact of the gabbro against the granite would seem to preclude the possibility of accounting for the more basic contact zones of the country rock on the basis of actual assimilation of some of the granite by the gabbro.

PEGMATITE

The most interesting thing about the pegmatite is its distribution, because it is very commonly directly associated with the gabbro masses. Many times the pegmatite, in the form of dikes or veins, may be seen cutting the gabbro (see plate 4) and hence the younger age of the pegmatite. This direct association of the very acid pegmatite with basic gabbro and its age intermediate between the basic intrusives — gabbro and diabase — are rather anomalous features for which the writer can offer no explanation.

Among other places where pegmatite may be seen cutting the gabbro are: (1) at the top of Hackensack mountain; (2) 1¼ miles south-southeast of Potter mountain; (3) 1¼ miles a little east of north of The Glen; (4) 1 mile south-southeast of The Glen; (5) 1⅓ miles northeast of Pottersville; (6) 1⅔ miles southeast of Chestertown; (7) 2½ miles southeast of Chestertown; and (8) 2¾ miles south-southeast of Chestertown. At most of these places the gabbro is shot through with small pegmatite veins. At the fourth named locality one dike is 50 feet long and 25 feet wide and very rich in big orthoclase and albite feldspar crystals. At the seventh named locality a small pegmatite dike contains fine crystals of biotite, muscovite and black tourmaline. At the sixth and eighth named localities there are pegmatite dikes 50 to 100 feet long with books of muscovite up to 5 or 6 inches across at the eighth locality.

Large pegmatite dikes are not common away from the gabbro, there being but two examples worthy of mention namely: just east of the old garnet mine south of Daggett pond where there are many poorly formed black tourmaline crystals up to 6 inches long, and one-quarter of a mile above the mouth of Mill creek where there is a dike 200 feet long and 40 feet wide in granitic syenite.

DIABASE

Mode of occurrence and distribution

In striking contrast with the neighboring gabbro, the diabase invariably occurs in typical dikes which have clearly broken through narrow fissures in the country rock. They vary in length from 20 or 30 feet to 200 yards, and in width from 5½ inches to 40 feet.

The chief features of occurrence are brought out in the following description of the largest dike of the region which lies at the western base of Heath mountain or 3 miles west-northwest of Warrensburg. This dike has a maximum width of 40 feet and a length of 200 yards. It is fine to medium grained toward the interior and very fine grained along the borders. It breaks through both Grenville and granite gneisses and the contacts are everywhere perfectly sharp, there being no evidence whatever of contact metamorphism. A number of small tongues, from 1 inch to 3 or 4 feet wide, branch off the large dike and extend as much as 25 or 30 feet into the country rock. One of these branches cuts a pegmatite dike and another cuts Grenville limestone. This large dike strikes across the foliation almost at right angles.

One and one-half miles southeast of Johnsburg a diabase dike, 2½ feet wide and 60 feet long, cuts Grenville quartzite parallel to the foliation. All of this rock is fine grained but exceptionally so at the contacts, and on one side an inch wide zone of basaltic glass or obsidian is perfectly developed with some very small tongues of glass extending into the country rock.

A typical diabase dike 4 feet wide cuts the gabbro stock three-quarters of a mile south of Warner pond. The dike has fine grained borders, sharp contacts against the gabbro, and is clearly traceable for 150 feet or more.

In all eleven diabase dikes were found, being well scattered over the quadrangle. Most of them cut across the foliation of the country rock at high angles, thus differing from the gabbros, and they probably have been forced up along joint planes. In nine of the eleven occurrences the dikes strike northeast and southwest which is quite the rule for such dikes in the eastern Adirondacks. So far as can be determined, these dikes all come up vertically through the country rock.

Megascopic and microscopic features

The diabase is a very dark bluish gray to almost black rock which, in all exposures, is hard and fresh except for the immediate surface which is often weathered to reddish brown.

The granularity and texture vary from glassy to very fine grained to medium grained diabasic, the finer grained rock being wholly confined to the borders and the diabasic texture nearly always being just visible to the naked eye in the typical medium grained rock. Except for the above named differences the diabase shows no facies whatever visible to the naked eye, and this again is in marked contrast with the gabbros. The diabase is wholly devoid of any metamorphism and inclusions of country rock are never found. The only minerals recognizable by the naked eye are the tiny feldspar laths and an occasional pyrite speck.

The whole range in mineralogical composition is brought out in the following table:

TABLE 9

Mineralogical composition of the diabase

	Slide no.	Andesine to labradorite	Augite	Biotite	Ilmenite	Pyrite	Glassy ground mass	Quartz	Apatite
1	8	47	25	22.5	4	½	......	little	little
2	48	55	37 Mostly chlorite		6	little	......	2	little
3	7	55	40 Mostly chlorite.		5	....	......	little	little
4	10	5	5	......	many specks	....	85	....	.....
5	9	55	14	......	5	little	25	1	.....

The remarkable similarity in composition is a striking feature. Nos. 1, 2, and 3 are typical holocrystalline diabases from widely separated dikes. Nos. 4 and 5 represent finer grained or border phases and have more or less glassy ground mass. No. 5 presents a striking appearance under the microscope because the feldspar crystals which are incipient and almost indeterminate tend toward sheaflike bundles (see plate 6, lower figure).

Number 1 of table 9, which may be regarded as typical of all the diabases, is from the large dike (above described) at the base of Heath mountain. The fine to medium grained rock shows an excellent diabasic texture visible even to the naked eye. Judging by the extinction angles, the broad laths of somewhat decomposed plagioclase range from andesine to labradorite in composition. Pale reddish brown augite, in stout prisms, shows a very faint pleochroism. It exhibits good cleavage and sometimes good crystal boundaries. The biotite is much changed to chlorite and stained with black iron oxid. The ilmenite often shows transition to leucoxene. Apatite occurs in tiny needles, and pyrite and quartz in small irregular grains, the latter being probably of secondary origin.

Chemical composition, norm, and mode

The diabase from the dike at the western base of Heath mountain has been analyzed for the writer by Prof. E. W. Morley.

Table 10

Chemical composition and norm of diabase

	Per cent	Mol	Ilm	Apat	Fluor	Na Cl	Orth	Alb	An	Mag	Diop	Hyper	Quartz
SiO_2	50.57	.843	....	....	....	....	120	276	134	....	126	153	34
Al_2O_3	13.58	.133	....	....	....	....	20	46	67	....	....	....	....
Fe_2O_3	3.26	.020	....	....	....	....	....	....	....	20	....	....	....
FeO	10.09	.140	33	....	....	....	....	....	....	20	26	61	....
MgO	4.98	.124	....	....	....	....	....	....	....	....	37	87	....
CaO	7.67	.137	....	7	2	....	....	....	67	....	61	....	....
Na_2O	2.92	.047	....	....	....	1	....	46	....	....	....	....	....
K_2O	1.89	.020	....	....	....	....	20	....	....	....	....	....	....
H_2O+	.16	......	....	....	....	....	....	....	....	....	....	....	....
H_2O-	.94	......	....	....	....	....	....	....	....	....	....	....	....
TiO_2	2.68	.033	33	....	....	....	....	....	....	....	....	....	....
P_2O_5	.28	.002	....	2	....	....	....	....	....	....	....	....	....
Cl	.09	.002	....	....	....	2	....	....	....	....	....	....	....
F	.09	.005	....	1	4	....	....	....	....	....	....	....	....
MnO	.36	.005	....	....	....	....	....	....	....	....	....	5	....
BaO	.09	.001	....	....	....	....	....	....	....	....	1	....	....
SrO	.10	.001	....	....	....	....	....	....	....	....	1	....	....
S	.03	......	....	....	....	....	....	....	....	....	....	....	....
Total	99.78												

Qtz	2.04	Sal.= 56.01
Orth	11.12	
Alb	24.10	
Anor	18.63	
NaCl	.12	
Mag	4.64	Fem.= 42.34
Ilm	5.02	
Apat	.67	
Fluor	.16	
Diop	14.44	
Hyper	17.41	
H_2O+S	1.13	
Total	99.48	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{56.01}{42.34} < \frac{5}{3} > \frac{3}{5}$ = III, Salfemane

Order, $\frac{QL}{F} = \frac{2.26}{53.85} < \frac{1}{7}$ = 5, Gallare

Rang, $\frac{K_2O^1 + Na_2O^1}{CaO^1} = \frac{67}{67} < \frac{5}{3} > \frac{3}{5}$ = 3, Camptonase

Subrang, $\frac{K_2O^1}{Na_2O^1} = \frac{20}{47} < \frac{3}{5} > \frac{1}{7}$ = 4, Camptonose

Table 11

Mode of diabase

	Units measured	Rel. vols.	S. G.	Units by weight	Percentage weights
Plagioclase	2 027	46.88	2.66	5 392	40.78
Biotite	975	22.55	3.20	3 120	23.59
Ilmenite	168	3.88	5.17	868	6.56
Augite	1 090	25.21	3.30	3 597	27.20
Pyrite	30	.69	5.00	150	1.13
Quartz	26	.60	2.65	69	.52
Apatite	8	.18	3.20	26	.19
	4 324	99.99	....	13 222	99.97

Thus, according to the old qualitative classification, the rock is a biotite-diabase, while under the new quantitative chemical classification it is a biotite-camptonose. The amounts of SiO_2, Al_2O_3, and CaO in the analysis strongly bear out the determination of the plagioclase as ranging from andesine to labradorite. Such a high content of FeO in the analysis makes it certain that the biotite is rich in ferrous iron, since there is not enough magnetite and augite to account for so much FeO. The sulphur appears too low as judged by the amount of pyrite visible even to the naked eye. The high TiO_2 shows either ilmenite or that the magnetite is decidedly titaniferous, though a little of the TiO_2 may be in the biotite. The low Fe_2O_3 content in the analysis favors the presence of ilmenite.

It is important to note that the analyses of the diabase and typical gabbro are very similar except for somewhat higher silica and lower lime in the diabase, this difference probably being due to the slightly more acid character of the plagioclase in the diabase. Thus the two rocks have quite certainly been derived from the same source of basic supply though at different times.

TABLE 12

Adirondack diabase analyses compared

	1	2	3	4	5	6
SiO_2	50.57	43.41	44.51	45.46	46.73	50.89
Al_2O_3	13.58	19.42	19.99	19.94	16.66	15.39
Fe_2O_3	3.26	5.72	7.22	15.36	3.56	5.77
FeO	10.09	6.69			8.45	
MgO	4.98	5.98	8.11	2.95	8.12	7.60
CaO	7.67	9.11	8.15	8.32	8.03	8.75
Na_2O	2.92	4.39	5.24	2.12	3.73	5.67
K_2O	1.89	.47	2.60	3.21	1.64	2.72
H_2O	1.10	3.00	2.93	2.30	2.39	2.46
TiO_2	2.68	.35	......	......	.03	....
P_2O_5	.28	......	......	......	.39	....
Cl	.09	......	......	......	.18	....
F	.09	......	......	......	.26	....
Cr_2O_3	......	......	......	......	.06	....
MnO	.36	......	......	......	trace	....
BaO	.09	......	......	......	.04	....
SrO	.10	......	......	......	......	....
S	.03	......	......	......	......	....
CO_2	......	2.00	......	......	......	....
	99.78	100.54	98.75	99.66	100.27	99.25

1 From western base of Heath mountain, North Creek sheet, Warren county. Analyst Morley.

2 From summit of Mt Marcy, Essex county. Analyst Leeds. N. Y. State Mus. 30th Annual Rep't, p. 102.

3 From shore of Upper Chateaugay lake, Clinton county. Analyst Eakle. Amer. Geol. July 1893, p. 35.

4 From Palmer Hill, Black Brook township, Clinton county. Analyst Kemp. U. S. Geol. Surv. Bul. 107, p. 26.

5 From Bellmont township, Franklin county, dike 13. Analyst Morley. N. Y. State Geol. 18th Annual Rep't, p. 120.

6 From shore of Upper Chateaugay lake, Clinton county. Analyst Eakle. *Op. cit.*, p. 35.

The North Creek sheet diabase (no. 1) is lower in Al_2O_3 and CaO, and higher in TiO_2 than any of the others. It is also somewhat more acid than usual for the diabases, due to the more acid character of the plagioclase feldspar.

Lack of variation of the diabase

Because of its remarkable homogeneity in composition, the diabase presents a marked contrast to the neighboring gabbro. The diabase never contains inclusions and, with a single very local exception below described, never shows any evidence of magmatic assimilation even in the largest masses. This difference is quite certainly due to the difference in the mode and condition of intrusion, the diabase having clearly been forced through comparatively narrow fissures in the country rock and near the earth's surface as the texture shows. In such intrusions magmatic stoping would be reduced to a minimum or absent.

Contact phenomena

A small dike, 5½ inches wide, which cuts the Grenville limestone at the asbestos mine three-quarters of a mile southeast of Thurman, shows contact phenomena which deserve special mention. Following is a description based upon thin sections and hand specimens (see plate 7).

Zone 1 This is typical, unaltered, medium grained, greenish gray, serpentine marble.

Zone 2 This zone, about one-third of an inch wide, lies along the contact with the diabase. It consists of a fine grained, dark green, well-baked serpentine marble.

Zone 3 One-sixth of an inch wide. Nearly black (greenish gray in thin section), glassy looking dike rock which shows an irregular but sharp boundary against the marble. It appears to consist largely of rather homogeneous, serpentinous material (bluish gray interference tints) which is apparently igneous glass into which serpentine marble has been fused. Occasional well-formed laths of plagioclase and many specks of magnetite occur. The outer 1 or 2 millimeters of this zone are very rich in magnetite specks. This zone shows a rapid transition into the next one.

Zone 4 One-third of an inch wide. Reddish brown, glassy looking. Apparently good igneous glass filled with many tiny specks of what seem to be magnetite and perhaps 10 per cent of plagioclase mostly in laths but some in stout prisms with distinct zonal structure. This grades perfectly into the next zone.

Zone 5 One-half of an inch wide. Pale green color and much like no. 4 except for absence of the tiny specks. The green color is due to serpentinous material which appears to have been absorbed by the molten mass. The contact between this and the next zone is rugged though pretty sharp.

Zone 6 Ordinary bluish black diabase from within the dike and with no serpentinous admixture. This rock is mostly a dark glass which contains 5 per cent plagioclase laths and 5 per cent pale reddish brown, euhedral augite crystals and numerous specks of presumably magnetite.

PALEOZOIC OUTLIERS

No actual outcrop of Paleozoic strata has been found within the borders of the quadrangle, but certain nearby Paleozoic outliers have an important bearing upon the geologic history of the region. Two of these outliers have been described by Professor Kemp, one of them being Little Falls dolomite which occurs at Schroon Lake village (Schroon Lake sheet), and the other being Potsdam sandstone which occurs near the village of North River (Thirteenth Lake sheet).

During the summer of 1910 the writer discovered a small Paleozoic outlier 1 mile south of the map edge and 1 mile due west of High Street village (Luzerne sheet). The exposures are rather poor and small but the rock is quite certainly in place with the strata lying in nearly horizontal position. Both sandstone and dolomite beds occur and it is not certain whether the rocks represent the passage beds of the Theresa formation or the contact between the Potsdam and the Little Falls dolomite, though the former is more probable. This outlier lies at 1400 feet elevation and not far to the west of the No. 9 mountain fault and on its downthrow side.

The important outlier at Wells (Lake Pleasant sheet), which shows rocks from Potsdam to Canajoharie, has been known since the early days of the State Survey. The nearby occurrences of Little Falls dolomite along the southern portion of Lake George should also be mentioned.

Within the map limits, certain drift boulders are significant as showing proximity to concealed outcrops or ledges which were scraped off by ice erosion. Thus a fragment of Potsdam sandstone 2 feet across and very angular was seen just east of the old garnet mine near Daggett pond, and many Potsdam fragments up to 1 foot across occur in the river valley bottom between Moon and Heath mountains.

The occurrences of early Paleozoic marine strata on all sides of the North Creek quadrangle furnish practically conclusive evidence that much, if not all, of the area of the quadrangle was covered by that early Paleozoic sea. Thus the Potsdam (upper Cambric) sea, which encroached over northern New York from the northeast, must have swept over the North Creek region and this was quite certainly succeeded by the Theresa and Little Falls seas. Regarding the presence or absence of the Ordovician sea, we have no positive knowledge, though the Wells outlier suggests that it, too, was present.

It is well known that when the Potsdam sea encroached upon the eastern Adirondacks, the region was greatly worn down to the condition of nearly a peneplain. Since some portions stood out above the general level of the peneplain, it is quite possible that the Potsdam sea, and even the later Cambric, did not cover the higher portions as Professor Kemp has suggested. At any rate the evidence is strong that very much if not all of the North Creek area was covered by the late Cambric sea and probably also by the Ordovician sea. The deposits made in those seas have all been removed by erosion except for the small outlying masses above described. It is important to note that each one of these outliers has been very considerably faulted downward from the original position of the strata and thus they have been protected against complete removal by erosion during so many million years.

STRUCTURAL FEATURES

FAULTS

General considerations. That the eastern Adirondacks are extensively faulted has been recognized for some years, but thus far comparatively little attention has been paid to the detailed study and mapping of these faults well within the Precambric area. The North Creek quadrangle, which lies in the midst of this eastern Adirondack faulted region, is literally cut to pieces by faults. On the accompanying geologic map the writer has indicated the positions of over forty faults, most of which show unmistakable evidences of their presence, while the others, shown on the map by the heavy broken lines, are more or less certainly present.

The faults are all of the normal type with fault planes vertical or very steep. Because of the character and structure of the rock masses and the lack of any well-defined stratigraphic relations, it is practically impossible to determine the actual amounts of displacement, though in many cases minimum approximations can be made. Such minimum figures commonly range from a few hundred to a thousand feet or more. One feature worthy of special mention is the frequent rapid diminution of throw within very short distances. Thus in many respects the North Creek faults are much like those of the Mohawk and Champlain valleys, which is to be expected as the faults of this whole eastern Adirondack region were all produced at the same time or times. With regard to the strike, however, the North Creek faults are rather exceptional because the general trend of the Adirondack faults is north-northeast by south-southwest, while within the North Creek quadrangle this trend is the rule only in its northern portion.

As a rule, faults within the Precambric area are difficult to locate and trace with any great degree of accuracy and certainty because of the general similarity of the rocks and the lack of ordinary fossiliferous strata. In the North Creek region, however, the conditions are particularly favorable for locating faults both because of the unusual excellence of exposures and the large amount of widely distributed weak Grenville strata.

Frequently the line of contact between the syenite or granite and the Grenville is very regular and sharp, the Grenville often seeming to dip under the igneous rock with the latter rising abruptly and to a great height above the Grenville. Among the best examples of such phenomenon are the southern sides of Huckleberry, Crane, and Little mountains, and the western sides of Oven, Prospect, Birch, and Potter mountains. There are only two possible explanations of this phenomenon, namely, either that the igneous rocks were intruded into the positions which they now occupy or that faulting has occurred. If this is to be explained simply on the basis of intrusion, then we are forced to assume a remarkably irregular surface

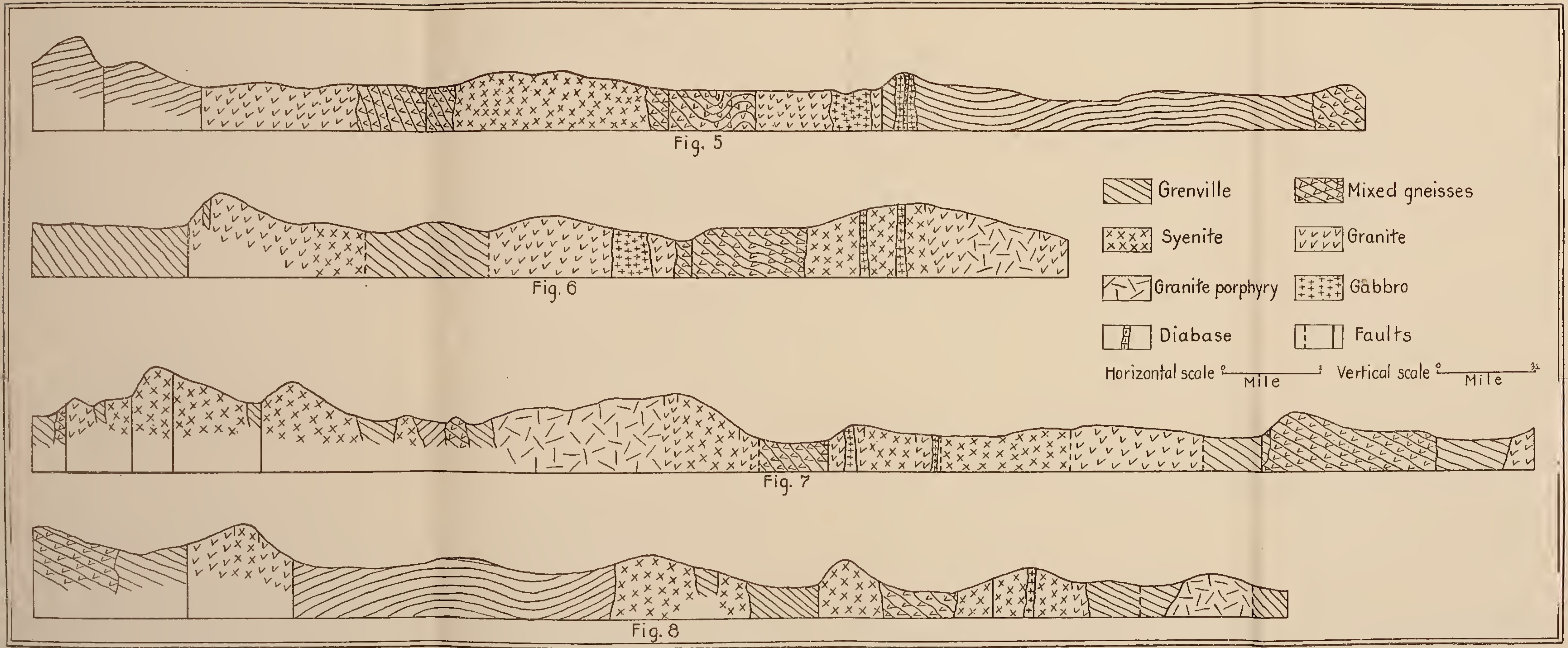


Fig. 5-8. Structure sections across the North Creek quadrangle. The position of the section lines is shown on the geologic map.

of the newly cooled magma and also that the molten masses, in all these cases, broke through the Grenville along very straight or regular lines often for miles. Both of these assumptions are out of harmony with well-known observations in other regions.

The very common dip of the Grenville downward against the faults is due to the fact that most of the prominent fault scarps face the west while the prevailing dip of the Grenville is toward the east.

Among the more positive criteria for the recognition of the faults are the following: (1) actual steep to vertical scarps, often in hard, perfectly homogeneous rock, and frequently in such positions as to preclude the possibility of their having been formed by ice or stream erosion; (2) the distinct tilting of the earth blocks gradually downward away from the scarps; (3) the frequent presence of actual crushed, sheared, or brecciated fault zones; and (4) the long, straight contact lines between the Grenville and the igneous rocks, with the latter rising abruptly high above the former.

What is the age of the faulting? That some, at least, occurred during Precambric time has been pretty well established but, so far as known, such faults are of minor importance and certainly have no appreciable influence upon existing topography. But a single case of such very ancient faulting has come under the writer's notice within the area of the quadrangle and this occurs along the road three-fifths of a mile southwest of Sullivan pond. A fault, plainly visible for 12 feet, there passes across a glaciated ledge of quartz syenite. On the east side, for a width of 7 or 8 feet, the whole mass is a fault breccia. This breccia is fine at the fault and coarser, with fragments up to 1½ feet across, away from the fault. The fault strikes north 30° east and is in no way related to existing topography.

There is good reason to think that considerable faulting occurred during the Paleozoic era after the deposition of the Ordovicic sediments because rocks of that age are involved in the faulting along the eastern and southern borders of the Adirondacks. Cushing has suggested that the faulting may have been initiated at the time of the Taconic revolution when the rocks immediately eastward were so greatly disturbed, but he says:[1] "The great earth disturbance (Appalachian revolution) which prevailed in the Appalachian zone toward the close of the Paleozoic would seem more likely to have brought about the major faulting of the region." We know that

[1] N. Y. State Mus. Bul. 95, p. 405.

the whole State was then upraised practically without folding, and the conditions were certainly favorable for extensive fracturing of the strata.

Any fault scarps or ridges produced during or at the close of the Paleozoic must have been quite or nearly obliterated during the long Mesozoic period of erosion. If so, how do we account for the present Adirondack ridges which follow fault lines? As a result of the uplift of the Cretacic peneplain one or both of the following things happened, namely, either that there was renewed faulting or that, as a result of unequal erosion (due to differences in rock character) on opposite sides of the faults, the old fault scarps were renewed. It is quite certain that both things occurred and thus we account for the present Adirondack fault ridges. That some of the faulting actually dates from the uplift of the Cretacic peneplain, or possibly even later, is proved by the existence of certain fault cliffs in perfectly homogeneous rock masses, and by the fact that many of the tilted fault blocks have been little modified by erosion since their formation. Among many good examples of fault scarps in homogeneous rocks are those on the west sides of Moon, Kelm, and Chase mountains, while tilted fault blocks little affected by erosion are those of Moon, Birch, Crane and Huckleberry mountains.

Little-Crane-Huckleberry mountain faults. The structural relations shown by these three mountain masses are truly remarkable and the faults are the most interesting within the quadrangle. The deep, narrow rift between Huckleberry and Crane mountains was carefully examined and, judging by the frequency of outcrops, it is quite certain that a narrow belt of Grenville separates the mountain masses as shown on the map. A narrow valley of Grenville, chiefly limestone, with almost continuous outcrops separates Crane mountain from the granite ridge just south. Likewise there is a valley of Grenville, chiefly limestone, immediately to the south of the granite ridge (Little mountain and its westward extension).

In each case the mountain mass of igneous rock presents a high and very steep to almost precipitous wall on the south side, and in each case the belt of Grenville comes abruptly against the igneous rock wall. A slight exception to the latter statement is along the southwestern base of Crane mountain where a small belt of syenite intervenes between the Grenville and the high mountain mass. Almost invariably the rocks of the Grenville belts dip at high angles downward and against the faults. The great

Plate 8

W. J. Miller, photo

Crane mountain as viewed from Thurman village. This great dome of quartz-syenite rises 2000 feet above the valley at its base. The valley is underlain with Grenville, chiefly limestone. The steep slope on the left (south) side is due to a fault scarp, and the down tilt of the great mountain block toward the right (north) is plainly shown. The escarpment at the summit is due to the passage of a minor fault.

bare wall of syenite rising to a height of a thousand feet or more on the south side of Crane mountain is a truly impressive sight as viewed from the valley or ridge just to the south. As viewed from the summit of Crane mountain, the sharp-crested granite ridge forming the westward extension of Little mountain bears a close resemblance to a typical hogback ridge. All these mountain masses show decided, though much more gradual, downward slopes toward the north, this being perfectly shown by Crane and Huckleberry mountains and not so well by the Little mountain ridge. Thus the general areal distribution and structural relations of the rocks, more especially the long, regular or straight contact lines between the Grenville and igneous rocks; the high, steep walls of igneous rocks rising above the Grenville; and the distinct downward tilt of the mountain blocks northward and away from the scarps make the presence of three faults here practically certain. The picture of Crane mountain (plate 8) clearly shows the character of this earth block with its steep scarp on the south and long northward slope.

For reasons already stated, nothing like exact figures can be given as to the amounts of displacement but, judging by the present height of the scarps, the throw of Crane mountain fault appears to be more than a thousand feet, while the throw of the Huckleberry and Little mountain ridge faults are no less than 500 to 800 feet. The very rapid dying out of these faults is rather remarkable, but perhaps not more so than in the case of the Batchellerville fault of the Broadalbin quadrangle recently described by the writer.

As shown on the geologic map, a minor fault extends across the top of Crane mountain and parallel to the great fault just south. Three high points, 2682, 2829, and 3254 feet respectively, are arranged along the crest of the fault scarp with very steep south fronts or cliffs. The scarp on the south side of the highest peak (3254 feet) is a sheer precipice more than 200 feet high, which forms what is locally called the "Nose" of Crane mountain. It is well shown in plate 8. At several places the line of fracture is marked by distinct crushed or sheared zones where the rock is biotitic and almost like a schist in appearance.

The eastern face of Crane mountain rises abruptly along a straight line to a height of more than a thousand feet, and certainly bears every resemblance to a fault scarp. This topographic evidence,

[1] N. Y. State Mus. Bul. 153, p. 45.

together with the fact that this abrupt change in slope occurs in homogeneous syenite and away from any possible stream action, makes the presence of a fault here quite certain.

The eastern face of Little mountain is also very steep, much more so in fact than the contour lines indicate, and the general topographic and structural relations here also strongly suggest faulting. Some signs of shearing were noted. The northward extension of this fracture (dotted on the map) is more doubtful though the topography, not well shown on the map, points to minor faulting there. The strike of these two last named faults is almost exactly at right angles to the other larger faults of the group.

Moose-No. 9 mountain faults. The Moose mountain fault, as shown on the map south of Thurman village, is really only the northern end of a very prominent fault which has formed the steep escarpment along the eastern side of Moose mountain (Luzerne sheet).

No. 9 mountain fault strikes due north and south and has caused the steep western front of the mountain. Some evidence of shearing was noted. The displacement appears to have been no less than 500 feet, and the eastward downtilt of the earth block is evident.

Potter-Birch-Heath mountain faults. The Potter-Birch mountain mass is a fine illustration of a fault block with steep western front and gradual slope away from the scarp toward the east. On the western side of Birch mountain there is a very distinct shear zone along which the syenite has been badly crushed and made to appear much like a biotite schist. The Grenville, mostly limestone, dips at high angles eastward sharply against the syenite along the fault. The very distinct curving in of the fault against the syenite mass is here better shown than for any other fault of the quadrangle. The steepest portion of the scarp is at Daggett pond where an almost precipitous wall of syenite rises 555 feet above the pond. Judging by the present topography, the displacement of this fault ranges from 300 to 600 feet, being greatest at Potter mountain.

The Heath mountain mass is a good illustration of a small fault block eastwardly downtilted. The displacement is no less than 300 or 400 feet. It is possible that this fault is really a continuation of the Potter mountain fault, though it is more than likely a separate fracture as shown on the map.

The small mountain of syenite lying just across the river from Heath mountain is a still smaller fault block much like that of Heath mountain.

Moon-Hackensack mountain fault. This is a well-defined fault whose presence is proved by most of the criteria generally applicable in this region. The strike is northwest-southeast and in perfect harmony with that of Moon and Hackensack mountains. The trend of the fault scarp is clearly marked by the topography, the western face of Moon mountain being especially high and steep (see plate 9). Between the two mountains the scarp is lowest because the weaker Grenville there has been worn down most rapidly. This whole earth block shows the eastward downtilt, particularly in the case of Moon mountain. In a large prospect hole at the western base of Hackensack mountain and close to the road there is much evidence of shearing along the fault. Near the source of the small stream along the fault and half way between the mountains there is a fine exhibition of crushed and brecciated Grenville gneiss. Sheared rock was also noted along the western side of Moon mountain. The maximum throw of this fault appears to have been no less than 600 feet.

County House mountain fault. This fault is shown dotted on the map because its presence is not altogether certain. The steep eastern front of the County House-Kelm mountain masses and the fact that the Grenville (much limestone) comes in rather sharply against the bases of these mountains are the principal evidences for the faulting. The Grenville here, contrary to the usual thing, either dips away from the fault or its strike is at high angles against the fault.

Kelm mountain fault. This is a good example of a fault wholly within a mass of very homogeneous, igneous rock. The fault scarp is much more in evidence than the contour lines suggest, and there is a rather distinct eastward downtilt of the block. Shear zones were noted in two or three places. The displacement is as much as 300 feet.

Millington brook fault. This fault lies along the eastern side of the valley of Millington brook and strikes north-northwest by south-southeast. Where it crosses the road, 1¼ miles southwest of Kelm pond, the rocks are considerably sheared and brecciated. On the western side of the small mountain (1302 feet), near the north end of the fault, sheared rock was also noted. The extension of this fault southward to the western base of County House mountain is somewhat doubtful though the relations of the rock masses and the topography strongly suggest it. The throw of this fault is probably not over a few hundred feet.

Chase mountain fault. This fault strikes nearly north and south and the chief evidences for its existence are the very prominent scarp in the homogeneous granite porphyry and some suggestions of shearing. The usual tilted character of the blocks is not here shown. This fault probably continues southward to join the Millington brook fault as indicated on the map.

Tripp mountain faults. A fault whose trend is almost exactly north and south lies along the western base of Tripp mountain as shown on the map. The evidence for this fault is largely topographic, such as the presence of a very distinct scarp along a straight line for several miles in homogeneous igneous rock, and also the rather distinct downslope toward the east from the scarp. Near the south end of the fault and on the west side of the hill (1221 feet) some sheared rock was noted, but for most part the line of the fault is covered with rock debris. A maximum displacement of no less than 300 to 400 feet seems to be shown.

The southeastern face of Tripp mountain is a steep scarp which has almost certainly been produced by faulting because of its presence in homogeneous granite porphyry and away from any considerable stream. A throw of several hundred feet is represented.

Tripp pond fault. This fault strikes northwest-southeast and passes along the north side of Tripp pond and along the bases of the mountains whose elevations are respectively 1662 and 1389 feet. The very steep scarp rising to a height of 700 feet and forming the southwestern face of the mountain (1662 feet) just north of Tripp pond is almost certainly a fault scarp. At the opposite end of the fault the scarp is distinctly traceable along the southwestern face of the low mountain (1389 feet) and the little hill just southwest of Sullivan pond. The scarp here strikes at a high angle across the foliation and in homogeneous rock.

Bull Rock mountain faults. These two faults form the western boundary of the mass of syenite which lies along the east-central margin of the map. The shorter one strikes northwest-southeast and lies along the western border of the Bull Rock mountain mass, and the smaller mountain (1560 feet) just to the northwest. Grenville, chiefly quartzite, dips downward sharply against the fault.

The longer fault follows a perfectly straight line of hills or low mountains whose elevations are respectively 1560, 1512, 1200, and 1140 feet, the throw of the fault apparently gradually diminishing toward the north. The Grenville in the valley immediately west of the fault consists of various gneisses with varying dips and

Plate 9

W. J. Miller, photo

The Moon mountain fault-scarp as seen from directly across the Hudson river, which is just visible in the foreground. Many exfoliation slabs can be seen near the mountain top. A heavy (wooded) talus slope covers the base of the mountain. The rock is quartz syenite.

strikes. The usual evidences prove the faulting, the eastward downtilt of the fault block being especially well shown. Neither of the two faults just described has a maximum displacement of more than a few hundred feet.

Brant lake faults. A very prominent fault, which may be called the Brant lake fault, passes along the northern side of the lake of the same name within the adjoining Bolton sheet. The lake clearly occupies a depression at the base of this fault scarp. Only the western end of this fault comes into the North Creek quadrangle where it passes along the southern base of the mountain at the village of Horicon. It can not be traced across the Schroon river. Near the village of Horicon distinctly sheared and slickensided rock may be seen in the granite quarry. At the village the displacement appears to be no less than 400 or 500 feet.

On the south side of the narrow valley at Horicon a smaller fault, parallel to the larger one, is clearly indicated by a crushed zone in the granitic syenite. The eastward extent of this fault is not known.

Chestertown faults. A prominent fault with northwest-southeast strike lies along the southwestern base of Prospect mountain and is thought to be continuous with the fault shown on the map just east of Loon lake. These two are certainly exactly in line and, though they have not been positively connected, they will be regarded as parts of the same line of fracture. At the Loon lake end the fault shows an almost vertical scarp 300 feet high where it passes along the western border of the gabbro stock. The scarp there consists of badly sheared gabbro, and Grenville limestone dips directly against the base of the scarp. The southwestern side of Prospect mountain is a fine example of a high, steep fault scarp with banded Grenville gneisses dipping eastward against the base of the mountain which consists of a granitelike mass of gneiss. A displacement of no less than 700 feet is shown here. The southern end of the fault is marked by a rather steep scarp several hundred feet high and in the homogeneous granite porphyry.

There is fairly good reason to think that another fault with north-south strike passes through the western edge of the village of Chestertown, but since its presence is not certain it is represented on the map by a broken line. The fairly prominent scarp which forms a long straight boundary between the Grenville and the igneous rocks is the chief evidence for considering a fault here. The fault plane is mostly concealed by heavy drift.

The Glen-Riparius fault. This fault, whose length is some 8 or 9 miles, is clearly the longest one lying wholly within the quadrangle. It is topographically very plainly marked, a whole line of low mountain peaks forming the crest of the scarp. This great fault block shows a very distinct downtilt toward the east which accounts for the peculiar drainage condition because no considerable streams enter the Hudson river from the east along the line of the fault but, instead, the streams all drain from the crest of the scarp down the eastward slope and into the Friends and Loon lake basins. The Hudson river itself has had its course determined along the base of the scarp. A displacement of from 300 to 600 feet is commonly shown.

Gage-Stockton mountain fault. As shown on the map by the heavy broken line, a prominent fault is thought to extend along the eastern bases of Mill, Stockton, and Gage mountains and southward to The Glen. The principal evidences for faulting here are the arrangement of the high, steep mountains along a regular line and the long, smooth contact between the areas of Grenville and mixed gneisses and the igneous rocks. The usual tilted character of the fault blocks is here not shown. Shear zones were not noted though this is of little significance because exposures on the line of the fault are very scarce. The displacement of this fault appears to be as much as 800 or 1000 feet.

If this fault is actually present, then the large wedge of Grenville and mixed gneisses in the valley bottom is of the nature of a through fault block.

Oven-Mill mountain faults. These faults are most likely parts of the same line of fracture, though the connection has not been positively traced. In each case Grenville (chiefly limestone) dips eastward and directly against the base of the mountain. The Oven mountain fault scarp, which rises nearly 900 feet and is very steep to almost precipitous, is an impressive sight as viewed from the west. An eastward downtilt of the block is fairly well shown. The Mill mountain scarp is not so steep but rises to a height of over 700 feet. Because of the much weaker Grenville between the two mountains, no distinct fault scarp is there present.

North Creek fault and branch. This prominent fault strikes north-northeast by south-southwest and passes through the village of North Creek. Northward from the village it is very clearly traceable as a topographic feature for at least 10 or 12 miles and well into the Schroon lake quadrangle along the west side of the

Plate 10

W. J. Miller, photo

View across the Hudson river from a point just south of the railroad station at Riverside, and typical of the region through which the river flows. The mountain consists of quartz-syenite. The Glen-Riparius fault, which the river follows for some miles, lies along the base of this mountain.

valley of Minerva stream. From North Creek to the map edge the line of the fault is marked by a distinct depression which has been formed along the belt of weakness. Except near the Hudson river where the weak Grenville is crossed by the fault, a well-defined fault scarp forms the upthrow side on the west and it is important to note that this scarp strikes at a high angle across the foliation of the rocks, thus proving the independence of the fault and foliation planes. One and one-fourth miles north of North Creek decomposed and somewhat crushed granite marks the passage of the fault. Just at the map edge the eastern face of the Moxham mountain mass is a fine illustration of a steep fault scarp rising to a height of 900 feet. Since the fault here passes through a great mass of rather homogeneous, igneous rock, it is certain that the amount of displacement is not less than 1000 feet. An interesting feature is the large inclusion of Grenville gneiss just south of Moxham mountain; it occupies such an unusual position because it lies on the upthrow side of the fault in a place fairly well protected from erosion.

In the stone quarry just east of the main fault and near the map edge, a fault plane with breccia is clearly exposed in both walls of the quarry. Its strike is north 30° east and it appears to be a minor fracture parallel to the larger one.

At the map edge a fault branches off the main line of fracture and follows the steep mountain side to Fuller pond. Just east of the pond the scarp of Grenville gneiss rises almost vertically for several hundred feet.

South of the village the North Creek fault is clearly traceable by the steep mountain sides of igneous rock against which the Grenville comes in contact along a straight or at least very regular line as far south as Baker's Mills (Thirteenth Lake sheet).

Holcombville fault. There is considerable evidence for a fault with a northwest-southeast strike along a nearly straight line passing through the village of Holcombville. It is represented by a broken line on the map because its presence is not regarded as conclusive. It is thought to extend for some miles into the Thirteenth Lake quadrangle or nearly to the village of North River. The chief evidences for faulting are the long, straight contacts of the Grenville against the bases of the high Oven mountain mass of igneous rock and the great mass of syenite within the Thirteenth Lake sheet. No shear zones were noted and the usual steep scarp and the tilted character of the fault block are absent.

Collins brook fault. The Collins brook fault lies nearly parallel to the Holcombville fault and it is named from the small brook which follows the base of the scarp near its north end. It is clearly marked by the topography for a distance of 5 miles between the Hudson river and Mill creek near Wevertown. The evidence for its existence is threefold, namely: (1) the long, regular scarp of granite whose crest is lined with peaks rising from 300 to 600 feet above the base of the scarp; (2) the long, smooth contact of the Grenville against the base of the scarp; and (3) the distinctly eastward downslope of the earth block away from the crest of the scarp.

Henderson mountain faults. The principal fault of this group strikes northeast-southwest along the western base of the Henderson mountain mass. Its position is plainly marked by the topography, and though the scarp is not as steep as usual, it is nevertheless very prominent and straight and cuts across the foliation of the rocks at a high angle. The sharp swing of the Hudson river northeastward for 1½ miles along the line of the fault has been determined by the crushed belt of weakness. North of the river the position of the stream which flows through Bird pond has also been determined by the fault. As judged by the height of the scarp at the south end and also at the base of Henderson mountain, the displacement is fully 700 feet. Where the fault crosses the belt of mixed gneisses the scarp is much less prominent because of the relative weakness of the rocks there. No tilting of this fault block is noticeable. This fault certainly continues for some 3 miles northward into the Schroon Lake quadrangle along the western bases of Green and Pine hills.

The second fault of this group strikes almost parallel to the Henderson mountain fault and lies at the eastern foot of the mountain whose elevation is 1915 feet. The very steep side of this mountain rises 700 feet and is another good example of a fault scarp wholly within homogeneous rock. Where the fault passes into the area of weaker mixed gneisses the scarp is much less prominent.

The third fault of this group is a small one which lies south of Igerna and along the north side of the Hudson river. It is wholly within the area of mixed gneisses but at some places almost vertical scarps rise fully 200 feet.

Schroon lake faults. The larger of the two faults here described strikes northeast-southwest and extends along the eastern side of the south end of Schroon lake and thence southward to the north end of Loon lake. At two places along Schroon lake the fairly steep scarp rises fully 400 feet. The southern end of the fault block is a mass of Grenville (chiefly quartzite) whose bold scarp at one place rises 400 feet. The whole fault block, especially the southern part, shows the usual downslope toward the east. This scarp strikes at a high angle across the foliation bands and hence it is difficult to account for except on the basis of faulting.

A smaller fault along the western side of the southern end of Schroon lake has a prominent scarp rising some 300 to 400 feet. Where it cuts across the gabbro stock near the map edge the fault scarp rises as a high vertical wall along which the rock is unusually soft and weathered and evidently sheared.

Loon Lake mountain fault. The short fault shown on the map just east of the north end of Loon lake and at the base of Loon Lake mountain is one of special interest. Here again the contours are not close enough together since the fault scarp which rises to a height of 700 feet is very steep, the upper 300 or 400 feet being a sheer precipice. We have here at once the highest steep ledge of Grenville and the finest example of a practically unaltered fault cliff within the quadrangle (see plate 10). The upper portion of the cliff consists of quartzite in thin to thick beds with low northeasterly dip so that the truncated edges of the quartzite layers are distinctly visible in the face of the cliff. The less steep scarp forming the western face of this fault block as well as its downtilt toward the east are due to the Schroon lake fault already described. Plate 11 gives a good idea of the appearance of this fault block mountain.

Other faults. The small fault north of Valentine pond strikes due north and south and shows a prominent scarp near its north end. The contours are not close enough together on the mountain side since the wall of rock, which rises fully 600 feet, is very steep to actually vertical in places. Hard, distinctly banded Grenville gneiss makes up the upper three-fourths of the wall and rests upon granite. The fault has broken sharply across the strike of the foliation of both the Grenville and granite.

As judged wholly by the topography, there appears to be a considerable fault block just west of Loon lake. The fault and its scarp lie from 1 to 1½ miles west of the lake and the downtilt toward the lake is very noticeable.

The shape of the lake basin and character of the topography suggest the presence of a fault along the west side of Friends lake.

As shown on the map, short faults are suggested at the eastern base of Mill mountain, the western base of Stockton mountain, and the northern base of Wolf pond mountain. Except for some evidence of shearing on the side of Stockton mountain, the only evidence for these faults is topographic, it being difficult to account for these steep scarps except on the basis of faulting.

The writer believes it quite likely that other, chiefly minor, faults occur within the quadrangle, but the ones above described are the only ones he feels justified in representing on the geologic map as actually or very probably present.

FOLIATION

All the rocks except the diabase and pegmatite show more or less of the foliated structure. It is best seen in the Grenville gneisses which are commonly distinctly banded due to differences in the composition of the beds, the foliation so far as observed always being parallel to the bedding. The syenite, granite, and granite porphyry are always gneissoid but never distinctly banded, the structure being accentuated by a drawing or flattening out of the dark colored minerals parallel to the foliation. The more basic pyroxene and hornblende syenites are, as a rule, not very gneissoid, as, for example, the Bull Rock mountain syenite. In fact it may be stated as a very general rule that the more basic, even and medium grained rocks of the syenite-granite series are least gneissoid; while the more acid rocks carrying hornblende and some biotite are clearly gneissoid; and the most acid rocks rich in quartz and biotite are very gneissoid. In these last named rocks the very presence of biotite flakes and the tendency of the quartz to become flattened favor the development of the foliated structure. Again, it often happens that when members of the great intrusive series, especially the granites, are close to the Grenville the rocks are more gneissoid. Thus, at the top of Heath mountain the pink granite is rather poorly gneissoid while at the base of the mountain it is very gneissoid.

The typical basic gabbro stocks seldom show a gneissoid structure except rather often in the narrow amphibolite borders. Some of the more acid stocks are clearly gneissoid.

An interesting feature is the common occurrence of rapid changes in degree of foliation even within the same rock ledge. Thus, just west of The Glen (on the mountain side) there are big ledges of

Plate 11

W. J. Miller, photo

The Loon Lake mountain fault-block, as viewed from a point three-fourths of a mile to the south-southwest. On the left (west) side the steep slope is that scarp of the larger of the two Schroon lake faults. The down-tilt of the block toward the east is perfectly shown. The cliff, several hundred feet high, which faces the south, is the scarp of the fault along the south side of the mountain. The upper portion of this mountain, which rises 600 feet above the valley, consists of Grenville quartzite and its lower portion of biotite-garnet gneiss.

hornblende granite. At times the rock is pinkish gray, medium to coarse grained, and not very gneissoid; while again, and by rapid changes, the rock is gray, fine grained, and very gneissoid to almost schistose. Both rock types have the same composition and both show signs of granulation, but the latter rock especially so. One of these clearly does not cut the other, but rather there is a rapid gradation from one to the other parallel to the foliation, and it seems clear that the fine grained, very gneissoid rocks were produced along belts of shearing perhaps at the time of the development of the foliation. Such a rapid transition from fine to medium grained granite is also well shown even in a hand specimen from the summit of Oven mountain.

Many dip and strike observations on the foliation were made, the more representative ones being plotted on the accompanying map. Strike observations can generally be made with a fair degree of accuracy, but dips can seldom be determined to nearer than 5 or 10 degrees. The amount of dip is usually rather moderate, most often ranging from 30 to 60 degrees. Considered as a whole, the prevailing strike of the foliation ranges from north and south to northwest and southeast with dips almost uniformly toward the east. The northern central portion is exceptional with its east and west strike and northward dip. Also there are important departures from the prevailing direction of dip and strike in certain Grenville areas as south of Johnsburg, south of Thurman, and between Pottersville and Starbuckville, in which areas the directions are very variable. On the Long lake sheet, according to Professor Cushing, the foliation is more erratic in the eruptives than in the Grenville, but here precisely the reverse is true.

FOLDING

Before any important general statements can be made regarding the character of the folding, a wider area will have to be studied. A striking feature is the almost uniform eastward to northeastward dip of the foliation, which suggests the possibility of isoclinal folding but aside from this uniform direction of dip, there is much evidence against such isoclinal folding. The generally moderate angles of dip; the perfect agreement of foliation and bedding planes even where the strikes and dips are erratic; and the utter lack of any evidence for repetition of the strata even in long sections like that of figure 1 are strong points against isoclinal folding. Professors Cushing and Kemp recently stated with reference to the Long Lake and Port Henry-Elizabethtown quadrangles that the Precambric rocks show no good evidence of having been more than moderately folded or tilted, and this appears to be true of the North Creek quadrangle as well.

Locally, the limestone and accompanying pyroxene gneiss may be intensely contorted or twisted, probably being due to the more plastic character of the limestone when subjected to great pressure. The pyroxenic bands are often pulled apart into small lens-like masses as shown in plate 11 and figure 9. Other fine cases of contorted limestone may be seen at the river bridge near Thurman station (off the map); just north of the Ferry at the river's edge (see plate 3); along the road 1¼ miles southwest of Kelm pond; and along the road a little east of north of County House mountain.

Figure 9 represents a sketch, drawn to scale, of a mass of limestone on the south side of Crane mountain which has been contorted and forced for 20 feet across the foliation bands of the associated hornblende-garnet gneiss.

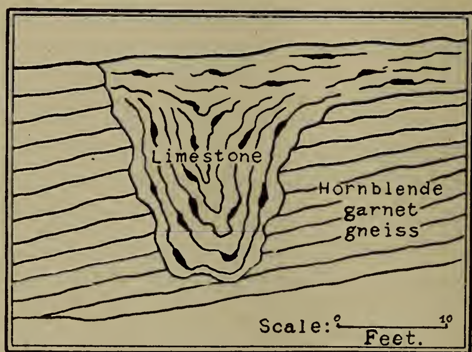


Fig. 9 Sketch showing a peculiar arrangement of Grenville rocks as seen by the roadside on the south side of Crane mountain and three-fifths of a mile from the summit of the mountain. The limestone has been contorted and forced across the foliation bands of the associated gneiss. The black patches represent drawnout fragments of pyroxenic gneiss.

SURFACE OF THE GREAT SYENITE-GRANITE INTRUSIVE MASS

The very ancient Grenville strata were invaded by a vast mass of molten syenite and granite which, in part, pushed aside or upward or engulfed some of the Grenville and, in part, left patches of greater or lesser extent practically intact. This has largely given rise to the very decided "patchwork" appearance of the geologic map.

Plate 12

W. J. Miller, photo

Contorted Grenville limestone as seen near the road one and one-half miles southeast of Johnsburg. The darker streaks are pyroxenic bands which have been badly twisted and drawn out.

The sharpness of the contact between the igneous rocks and the Grenville and the altitude of the igneous masses above the Grenville have often been accentuated by the faulting, but in spite of this some idea of the irregular surface of the great intrusive mass may be gained. Thus, the Grenville between Kelm and County House mountains occupies a depression fully 300 or 400 feet deep in the granite porphyry; while between Mill and Oven mountains the Grenville occupies a depression some 700 or 800 feet deep in the granite. Even if we grant the possibility of some faulting of the Pine-Gage mountain mass, it seems clear that this igneous rock rose by intrusion some hundreds of feet through the Grenville. In spite of the accentuated heights of the igneous masses of Hackensack, Moon, Heath, Potter, Huckleberry, and Crane mountains, it seems necessary to regard a considerable amount of the elevation of the igneous rocks above the Grenville as due to the intrusion itself. The only other alternative is the untenable view that faults completely surround these igneous bodies.

In general, then, we see that the great intrusive body often shows irregularities on its surface which vary in altitude by hundreds of feet within from 1 to 3 or 4 miles.

TOPOGRAPHY

RELATION OF TOPOGRAPHY TO ROCK CHARACTER

The surface configuration of the North Creek sheet is almost perfectly adjusted to rock character. A glance at the geologic map will show that the Grenville rocks, with few exceptions, occupy the lowlands; this is because of the relative weakness of those rocks as compared with the intrusives. The limestone areas or belts, being weakest of all, are invariably found in the valleys, and stream courses have commonly developed along such belts. Occasionally the more resistant Grenville gneisses, even where unaffected by faulting, have stood out fairly well against erosion as, for example, south of Valentine pond and south-southwest of Thurman. The Grenville quartzite being quite pure and very resistant usually stands out fairly conspicuously in the Grenville areas. This is well shown in the area south of Warner pond, though the height is there accentuated by faulting. The steep slope of the quartzite ridge east of Tripp pond appears to be due to more rapid wearing away of the much weaker underlying Grenville. In the mixed gneiss areas, particularly where the Grenville is abundant, the topographic development has been very similar to that of the Grenville areas.

The igneous rocks, where homogeneous and free from Grenville inclusions, without exception form the highest mountain masses. Occasionally the gabbro bosses appear to be slightly more resistant than the country rock and they then form the tops of low mountains or hills.

Another topographic feature often locally conspicuous is the sand flat or flat-topped sand terrace. Among the best examples are: in the vicinity of Warrensburg and Pottersville, west of Starbuckville, southwest of North Creek, and at a number of places southwest of Johnsburg. These represent delta deposits which were formed in glacial lakes which will be described in the succeeding pages.

RELATION OF TOPOGRAPHY TO ROCK STRUCTURES

Some of the most prominent topographic features of the quadrangle are the bold escarpments, more or less well-defined ridges, and isolated mountain masses or domes of igneous rock. These rock domes will be especially treated under the next heading. Most of the escarpments or ridges are due to faulting and have already been described. Some ridges, however, especially those in the Grenville areas, are due to other structural features combined with rock character. Thus the prominent ridge of gneiss which runs several miles southeastward from North Creek is due to the fact that a belt of weak limestone everywhere dips sharply under the harder rock of the ridge. The ridge south of Valentine pond is to be explained in a similar manner. Many small streams in the Grenville have developed along structural belts of weakness.

In the igneous rocks, too, there is a notable tendency for local short ridges and valleys to develop along lines parallel to the direction of foliation.

The most remarkable topographic feature in the whole region is the deep, narrow rift between Crane and Huckleberry mountains, which is certainly due to a combination of faulting, a belt of weak Grenville, and some erosion since the faulting.

EXFOLIATION DOMES [1]

One of the most striking features of the landscape, especially in the southern two-thirds of the quadrangle, is the prevalence of distinct, isolated, domelike, topographic forms which rise hundreds

[1] For a fuller discussion of this subject, see paper by the writer in N. Y. State Mus. Bul. 149, p. 187–94.

Plate 13

W. J. Miller, photo

Mill mountain, as seen from a point three-fourths of a mile to the southwest. This is a perfectly isolated dome of gray to pinkish-gray granite which rises fully 700 feet above the surrounding country.

Plate 14

W. J. Miller, photo

Potter mountain, four miles west-northwest of Warrensburgh, as viewed from a point one mile south-southwest. Quartz-syenite makes up the mountain mass, while Grenville limestone underlies the valley in the foreground. This mountain is a fine example of the exfoliation domes which are so common within the quadrangle. The dome rises 700 feet above the valley.

of feet above the comparatively lowland of the region. A comparison of the North Creek sheet with all other published Adirondack maps shows that, from the physiographic standpoint, this region is noticeably different from the Adirondacks in general.

Some of the best examples of such domes are: Kelm, Chase, Tripp, Hackensack, Moon, Heath, Potter, Birch, No. 9, Little, Crane, Huckleberry, Mill, Stockton, and Prospect mountains. The greatest of these domes is Crane mountain which rises 2000 feet above the immediately surrounding country. The upper 1000 to 1500 feet of this mountain are very steep to almost precipitous on all sides except the north making this great rock dome a grand sight as viewed from Thurman (see plate 8). Mill and Stockton mountains deserve special mention because they rise as two great isolated masses above the comparatively low and featureless surrounding country and form conspicuous features of the landscape as viewed from any of the higher points for a number of miles around (see plate 13). As viewed from the south, Potter mountain is a fine example of a rock dome which rises 700 feet above the general level of the country (see plate 14).

The domes may be classified under three headings according to shape: (1) those with nearly circular bases and which are very symmetrical and almost uniformly steep on all sides, as Potash, Mill, and Stockton mountains and the top of Kelm mountain; (2) those with elliptical bases and represented by nearly concentric elliptical contours to the summit, as Moon, Birch, No. 9, and Huckleberry mountains; and (3) those of irregular shape as shown on a large scale by Crane mountain and many smaller masses.

After climbing all the domes the writer has been impressed by the almost universal occurrence of exfoliation on a large scale over their surfaces. These mountains are literally peeling or shelling off by the removal of exfoliation sheets of great size, some having been noted as much as 50 to 75 feet across and from 1 to 3 feet thick. Among many other good places to observe this phenomenon are on the west or south sides of Moon, Crane, or Huckleberry mountains. Not infrequently, especially during the fall and spring months, slabs loosen up and go thundering down the mountain sides. Though the rocks are all clearly gneissoid, the exfoliation appears entirely to disregard this structure and often great sheets come off at right angles to the foliation.

This very common occurrence of exfoliation domes in the region the writer believes to be due to a combination of factors especially prominent in this part of the Adirondacks. Among these factors are: (1) character and distribution of the rocks whereby small to large masses of hard, homogeneous, igneous rocks have broken through the comparatively weak Grenville strata to produce a sort of "patchwork" effect so that, as a result of long erosion, the hard, igneous masses have stood out prominently above the Grenville; (2) faulting, whereby the "patchwork" effect and steep scarps have been either produced or sharply accentuated; (3) glaciation, whereby the isolated mountains of igneous rock were swept clean of decomposed surface rock and more or less smoothed or rounded off, thus favoring postglacial exfoliation; and (4) temperature changes, humidity etc., whereby the bare slopes of the isolated elevations of crystalline rock, under the conditions of comparatively rapid temperature changes in this the driest part of the State, are favorable for exfoliation.

PENEPLAINS

It is well known, especially as a result of the work of Professor Kemp and, more recently, that of Professor Cushing on the Saratoga sheet and of the writer on the Broadalbin sheet, that the southeastern Adirondack region had been worn down to the condition of a fairly good peneplain immediately prior to the advance of the upper Cambric (Potsdam) sea. Altitudes above the general peneplain level were not over a few hundred feet at the most. This conclusion has been reached through a study of those places along the borders of the Adirondacks where the Paleozoic rocks directly overlie the Precambrics. The position of the North Creek quadrangle renders it practically certain that this very ancient (Cambric) peneplain extended over its area, but because of the extensive faulting and erosion of the region, that old peneplain surface is nowhere certainly recognizable.

Again, it is well known that, by the close of the Mesozoic era, a fairly well-developed peneplain condition had once more been produced over this region in common with southern New England, New York, and the northern Appalachians. Professor Davis has shown[1] that the Berkshire hills area, during the late Mesozoic, had been worn down to a fairly good peneplain with occasional low mountains (monadnocks) rising above the general level. There is strong reason to believe that a similar condition prevailed over the southeastern Adirondack region, but with the monadnock

[1] Physical Geography of Southern New England in Physiography of the United States.

feature probably even more prominent. The comparatively even sky line of the western Adirondacks together with the high plateau called Tug Hill just west of the Black River valley, practically prove the former peneplain condition of that portion of the Adirondacks. This peneplain is known to have been elevated late in the Cretacic period or the early Tertiary period and, as already stated, much of the faulting of the eastern Adirondacks occurred at the time of that great uplift or even later. Thus the fact that this peneplain had considerable irregularities on its surface, combined with the facts of excessive tilting of the earth blocks by faulting and subsequent erosion, have quite effectually masked even this later peneplain surface. Doctor Ogilvie says with reference to the Paradox lake quadrangle,[1] that the even sky line of some of the mountains suggests an uplifted peneplain, and also that the long, smooth, eastward slopes of the fault blocks probably represent portions of the peneplain surface which were produced before the faulting. Similar evidences occur within the North Creek quadrangle as, for example, the rather even sky lines of the Henderson, Pine-Gage, Huckleberry, and Chase mountain masses, and the numerous eastward-sloping fault blocks already described. Anything like accurate knowledge of the character of this Mesozoic peneplain within the map limits is, however, lacking.

GLACIAL AND POSTGLACIAL GEOLOGY

CHANGES OF LEVEL

It is important to recall the well-known fact that the eastern portion of North America, including the Adirondack region, immediately preceding and doubtless during a good part of the Glacial epoch was notably higher than it is today. The submerged channels of the lower Hudson and St Lawrence rivers prove that the land there must have been something more than 1000 feet higher than now in order to have allowed the channel cutting. Toward the closing stages of the Ice age, and directly after it, there was a submergence of the whole region to below the present level as shown by the so-called raised beaches or delta deposits in the Hudson and Champlain valleys. In the Champlain valley the deposits are chiefly clays which were formed in an arm of the sea as proved by the presence of marine fossils. These deposits are now several hundred feet above sea level in the Champlain valley, which proves

[1] N. Y. State Mus. Bul. 96, p. 468.

at once that during the time of maximum subsidence the region stood several hundred feet lower than now, and that the most recent land movement has been one of elevation which has brought the marine deposits to their present position several hundred feet above sea level. This last (upward) movement has a direct bearing upon the glacial lake deposits of the North Creek quadrangle, and it is important to note that this upward movement was differential with greatest uplift toward the north. Using the figures of Professor Woodworth, the greater uplift of the land toward the north, passing along the southern part of the Champlain valley, has amounted to about 3½ feet a mile.[1] Practically this same figure may be applied to the North Creek area since it is so close to the southern end of the Champlain valley.

DIRECTION OF ICE FLOW

The evidence is conclusive that the North Creek quadrangle was vigorously glaciated. Many widely distributed glacial striae — sixty in all — have been observed within the map limits and are all recorded on the geologic map. Such a large number of striae is very unusual, certainly being far greater than for any other quadrangle so far mapped in the eastern, central, or southern Adirondacks. As usual the striae are most frequently seen along the highways in the valleys and on ledges from which the glacial drift covering has recently been removed. A number of striae have been found away from the roads and even on mountain sides, but never on mountain tops because where exposed on the bare ledges they have been obliterated by postglacial weathering.

Of the sixty recorded striae, the extreme range in direction is only from south 20° east to south 20° west, with the north-south direction nearly an average. In fact many of the striae do run north-south and very few vary more than 10° either side of this. The direction of ice movement indicated by these striae is exceptional for the central and eastern Adirondacks as judged by observations made on the Long lake, Paradox lake, and Elizabethtown-Port Henry sheets over which areas the general movement was southwestward at the time of maximum glaciation. The reason for the southward movement over the North Creek sheet is not an easy thing to account for, though it may possibly have been due to a crowding of the ice into the Hudson valley and a local deflection of the general southwesterly current where the ice flowed

[1] N. Y. State Mus. Bul. 84, p. 206, 228 and plate 28.

against the much higher mountains which are arranged along the eastern side of the adjoining Thirteenth Lake sheet.

Some of the striae are so situated in valleys as to suggest that, locally at least, the ice currents followed the valleys, but many others are situated wholly without reference to the topography. Among the best examples of striae which are significant as proving that the general ice movement was irrespective of even the major topographic features are the following: just north of Mud pond and immediately south of the Huckleberry-Crane-Little mountain masses, thus showing the retention of the southward course in spite of those mountains; immediately under the steep fault scarp on the east side of Loon lake; at the north bases of Pine and Gage mountains, showing that the ice current headed straight for those high mountains; and on the hilltop just northwest of Johnsburg where the ice left its record after having plowed diagonally up the hill for an altitude of several hundred feet instead of following the valley.

The great depth of ice over the region is proved by the frequent occurrence of drift boulders even on the high mountains, the high altitudes of some of the striae, and the glacial lake on Crane mountain. Some of the striae at considerable altitudes are as follows: north of Mud pond (southwest corner) at nearly 2000 feet; 2 miles east of Cherry ridge at from 1500 to 1600 feet; west base of No. 9 mountain at 1600 feet; 2½ miles southwest of Johnsburg at 1550 feet; on the side of Stockton mountain at over 1500 feet; and one-half of a mile northwest of Johnsburg on a hilltop at 1480 feet. On this basis, granting a fairly level ice surface, the depth of ice must have been at least 1000 feet or the difference between these highest striae and the Hudson river to the east. However, the presence of the glacial lake with drift dam well up on Crane mountain, and at an altitude of 2620 feet, shows that the ice was deep enough to cover the mountain that high up at least. According to this the ice must have been at least 1500 feet deep in the valley just north of Thurman and fully 2000 feet deep in the valley of the Hudson river.

ICE EROSION

To say the least, ice erosion was very effective in the removal of nearly all preglacial soils, decomposed rock, and loose joint blocks. The mountains were swept clean of such materials and left standing as more or less rounded off bare rock ledges, while during the retreat of the great ice sheet the valleys were partially filled with drift deposits. Decomposed rock material of preglacial age can now be seen at very few localities and those in specially sheltered places on steep south slopes where ice erosion was very ineffective. One such place is along the road 1 mile east-northeast of Wevertown at the south base of the mountain where the granite is decomposed, and another is just west of Crane mountain where the south side of a ridge of hornblende gneiss is badly decomposed to a reddish brown color.

Where favorably situated with reference to the direction of ice flow, the fault scarps were freshened up chiefly by the removal of the heavy talus slopes. An especially noteworthy example is the steep scarp 1⅓ miles north of Valentine pond where, on the nearly vertical wall of rock, good glacial striae may be seen. Heavy talus deposits which were not favorably situated for removal by ice erosion occur at the base of the Loon lake mountain scarp on the south side, and also at the base of the scarp next to the south.

There is good evidence for vigorous ice erosion in the valleys in the southeastern portion of the quadrangle, some of the facts favoring this view being: (1) the abundance of scratched, polished, and rounded rock surfaces; (2) the comparative freshness of the rocks, even in the case of the weak Grenville; (3) the unusual weakness of much of the rock, especially limestone, which occupies the valleys; (4) the fact that these belts of weak rock must have been deeply decomposed during the long preglacial time, thus favoring extensive removal of material; and (5) the north-south movement of the ice being parallel to the Grenville valleys and hence being favorable for ice erosion because of easy flowage of the deep ice through the valleys. Other Grenville valleys were doubtlessly also similarly lowered by ice erosion.

GLACIAL DEPOSITS

Glacial boulders or erratics are very common over the entire area and, as usual, most of them are of local origin. This fact of local origin was successfully employed to locate certain important outcrops, especially of gabbro or diabase, by tracing the line of boulders to the parent ledge. All sorts of Precambric rocks of the region are represented among the boulders, the granite and syenite naturally being the most common. A type of boulder wholly derived from without the quadrangle, and especially abundant in its northern portion, is the coarse grained anorthosite whose nearest parent ledges are in the northern portion of the Schroon lake sheet. Such boulders several feet across are frequently encountered. The only Paleozoic rock boulders noted were of Potsdam sandstone and, as already stated, these are nearly all confined to the Hudson valley between Heath and Moon mountains.

Glacial till or ground moraine material is quite widespread, especially over the lowlands, but no great thickness was noted at any place. It would seem that more material was scraped off by ice erosion than was deposited as till. As would be expected from the nature of the rocks, the till is always sandy or gravelly and generally filled with boulders. Not a single good example of real boulder clay was observed.

Kames are of uncommon occurrence. Three or four good ones, large enough to be shown by the contour lines, lie in the little valley a mile west of No. 9 mountain. Some other stratified sand and gravel deposits of rather doubtful kame origin occur in the valley between Chestertown and Tripp pond.

But one fairly well-defined boulder moraine came to the writer's notice and this is quite clearly traceable as a belt 1 to 3 miles wide from the vicinty of South Horicon westward around Prospect mountain, thence across the southern part of Loon lake and a mile or so southward, thence over the southern end of the ridge just west of the lake, and nearly to the river. The ice front must have been nearly stationary for some time along this line to allow the accumulation of so many boulders.

GLACIAL LAKES

Glacial Lake Warrensburg. This extinct glacial lake, recently described by the writer, is so named because of the location of the village of Warrensburg upon the old lake deposit which is especially well shown as a sand plain area between the village and the Hudson river. The concordant altitudes of this sand flat, where unaffected by subsequent erosion; the remarkable freedom of the surface from boulders; and the crudely stratified character of the material as shown in cuts all afford conclusive evidence for static water conditions here, the sand plain material having been formed as a delta deposit in the lake. This is a good example of a small pitted sand plain, there being two notable depressions (one containing a pond) below the level of the plain. Such depressions are thought to be due either to unequal deposition of the delta material or the presence of large buried blocks of ice which on melting would leave the depressions. The contact of the lake surface, at its height, with the surrounding land is quite accurately indicated by the 760 foot contour line but, because of postglacial changes of level, the actual altitude of the lake above the sea is not known. On a line passing east and west through Warrensburg the main body of water showed its greatest width of about 3 miles. Clearly defined sand terraces, the highest of which always rise to the 760 or 780 foot contour lines, prove that important arms of the lake extended fully 9 miles up the Schroon river valley above Warrensburg; nearly 4 miles up the Hudson valley above the mouth of the Schroon; and at least 2 miles down the Hudson from the mouth of the Schroon. The altitudes of these sand terraces gradually increase slightly toward the north because of the postglacial warping of the region as explained on page 66.

In the vicinity of Warrensburg, and especially along the Schroon river, the lake deposits, though deeply trenched, have seldom been cut through to the underlying rock. As a result of the meandering of the Hudson and Schroon rivers, during the process of trenching the old lake deposits, fine terraces have been developed. Such terraces are particularly well shown between Potter, Heath, and Moon mountains where they are at two or three different levels and from a quarter to a half mile back from the river as the contour lines partly indicate.

The cause of the standing water was a blockade, probably of glacial drift, in the Stony Creek gorge (Luzerne sheet).

Glacial Lake Pottersville. This lake, here described for the first time, must take rank as one of the largest and most interesting extinct glacial lakes yet recognized in the Adirondacks. It is so named because the best example of sand flat delta deposit formed in the lake lies in the vicinity of Pottersville. This sand plain covers fully a square mile at an altitude of about 800 feet, though the highest waterlaid sands and gravels occur from one-third to two-thirds of a mile northwest of the village and at an altitude of nearly 900 feet. This material was all formed as a delta deposit by Trout brook in a body of water which stood at a level corresponding approximately to the present 900 foot contour line at Pottersville. This body of water was Lake Pottersville of which Schroon lake is only a shrunken remnant. The

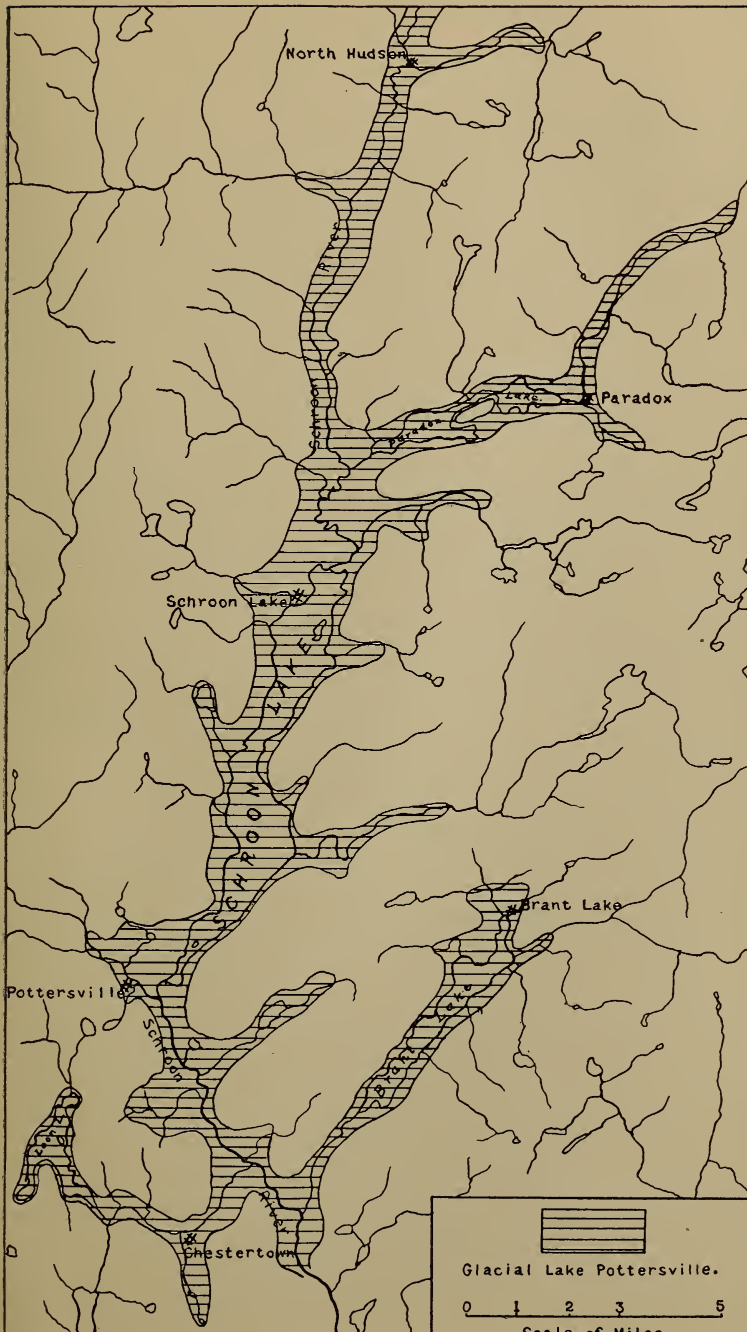


Fig. 10 Sketch map to show the extent of Glacial Lake Pottersville

existence of many sand flat delta or lake deposits makes it practically certain that this was a very extensive lake. It extended northward up the Schroon river as a long, narrow body of water at least as far as North Hudson, with a branch extending eastward to form an enlarged Paradox lake. Southward from Pottersville, all the lowland (below the 880 foot contour) southward to South Horicon and Meade pond (south of Chestertown) was occupied by the lake, with a prominent branch extending northeastward over the Brant lake area, and a smaller branch over Valentine pond. Another branch appears to have reached northwestward from Chestertown over the Loon lake area, though this is not quite so certain. The dam which held this water at so high a level was quite certainly one of glacial drift across what is now the deep, narrow channel of Schroon river 1 mile south of South Horicon. It is important to note in this connection that the boulder moraine, above described, crosses the river here. The Schroon lake reservoir, which may some day be built by the State by means of an artificial dam across the river at this same point, would largely restore the former lake.

Sand terraces around Brant lake, especially toward the east end along Mill brook, prove the former higher water level of that lake. Around Loon lake there are suggestions of lake deposits about 10 or 15 feet above the present water level but they are not very decisive. In the immediate vicinity of Chestertown and one-half of a mile west of Starbuckville, there are waterlaid sands or sand flats reaching altitudes of about 880 feet as nearly as can be judged from the contour lines. At Pottersville the delta material lies at from 880 to 900 feet; north of Schroon lake village up to 920 feet; and at North Hudson (Paradox lake sheet) up to 960 feet. Between Schroon lake village and North Hudson there is an almost continuous succession of such terraces along Schroon river, with gradually increasing altitudes toward the north. The rate of increasing northward elevation of these old lake delta deposits is in almost perfect harmony with the figures given by Professor Woodworth for the warping of the Lake Champlain terraces. As stated on page 66, the rate of northward increase at the latitude of Schroon lake should be about 3½ feet a mile. The altitude of the terraces at Chestertown is 880 feet; at Schroon Lake village 920 feet; and at North Hudson 960 feet. This is a total difference in altitude of 80 feet in the distance of 22 miles from Chestertown to North Hudson, or at the rate of 3.6+ feet a mile, which is very close to the figure given by Woodworth for the lower Champlain valley.

Glacial Lake Johnsburg. This was a small irregular shaped lake extending for about 2½ miles southwestward from Johnsburg as proved by a number of well-distributed sand flats or terraces at, or a little above, the 1300 foot contour line which approximately marks the old shore line. The best terraces, practically unrepresented on the contour map, are : two-thirds of a mile west, three-quarters of a mile southwest, three-quarters of a mile south-southwest, and at several places about 2 miles south-southwest of Johnsburg.

The cause of this static water condition appears to have been either an ice or glacial drift dam across the Mill creek channel at or not far east of Johnsburg.

Glacial Lake North Creek. The former presence of a lake in the vicinity of North Creek is proved by the existence of thick stratified sands, comprising terraces and flats. South of the village the sands show a depth of over 100 feet where they have been trenched by the small creek. Holcombville lies on a sand flat at 1160 feet, and the tongue of sand just southwest of North Creek rises to nearly the same altitude. Just north of the river the sands were, no doubt, largely removed by postglacial stream work. From 1½ to 2 miles north-northeast of North Creek (along the new State road) there are stratified sands and gravels running up as high as 1140 or possibly 1160 feet, and these seem to correlate with the deposits south of the village. The precise location of the retaining dam of this lake can not be given but it was either ice or drift, probably the latter, across the Hudson channel not over 2 miles east of North Creek.

One-half of a mile due east of Holcombville there is a small but finely developed flat-topped sand terrace at an altitude of 1240 feet. It extends out as a distinct apron from the mountain side of syenite. The depth of sand in this terrace is fully 200 feet, and it was probably formed in a small, marginal, high level lake when the ice was still present.

The Glen glacial lake. This body of water extended from near the headwater of Millington brook northwestward to the Hudson river, thence along the river channel past The Glen, and to near the mouth of Mill creek. Sand flats at an altitude of 800 feet or a little over, are well shown from 1 to 1½ miles east of the mouth of Millington brook, and a perfect sand terrace, fully 200 yards wide, three-quarters of a mile long, and at an altitude of about 800 feet, lies against a granite ridge two-thirds of a mile northeast of the mouth of the brook. One-half of a mile above the mouth of Potter brook, and also nearly 2 miles above its mouth, are perfect, small sand terraces at from 800 to 820 feet. At The Glen the railroad passes along the base of a fine flat-topped terrace which rises over 60 feet above the track. It is not shown on the map but by lock level its altitude was found to be a little over 800 feet. From 1 to 2 miles north of The Glen and on the east side of the river there is an extensive sand and gravel flat whose altitude is about 820 feet.

It is interesting to note that the coarsest deposits are toward the north because there the Hudson river with its load of debris entered the lake. The deposits of this extinct lake also rise gradually toward the north because of the postglacial land tilting. Near The Glen the lake was very narrow. The water of this lake appears to have been ponded by a drift dam across the Hudson river just below the mouth of Millington brook.

Other extinct lakes. Many other smaller glacial lakes, now either wholly or partly extinct, occur within the map limits. Thus Tripp pond was formerly much larger as shown by a number of fine flat-topped sand terraces lying at from 1020 to 1040 feet. The former lake was over 2 miles long with a drift dam a little over a mile north of the present lake.

The little valley shown on the map 2 miles southeast of Chestertown is certainly an old lake bottom. Most of the swamp areas are also old lake or pond bottoms.

Existing lakes. None of the lakes of the quadrangle are of preglacial origin. Some of them, such as Schroon lake, Valentine pond, Tripp pond, Smith pond, and probably Loon lake, are merely shrunken remnants of former larger bodies of water as already described. The waters of all the lakes and ponds are held in either by glacial drift or old lake deposit dams and most of them show evidence of having been at more or less higher levels. Some of the ponds seem to occupy depressions in the irregularly deposited drift. Ice erosion may have been effective in deepening some of the basins as, for example, that of Friends lake, though positive proof is wholly lacking.

POSTGLACIAL DRAINAGE CHANGES

Aside from the destruction or partial destruction of glacial lakes by cutting down the outlets or filling them up or both, and the moderate amount of downcutting by the larger streams with resulting development of terraces, there appear to have been no important drainage changes. Due to the irregular distribution of the glacial drift many of the small streams have postglacial courses, but the larger streams, like the Hudson and Schroon rivers, are believed to follow practically their preglacial channels which are well adjusted to the character and structures of the rock masses over which they flow.

In a recent paper [1] the writer discussed certain important postglacial drainage changes in the southeastern Adirondacks, and since one of the changes concerns the Hudson river immediately after it leaves the North Creek sheet, a very brief statement will here be made.

Instead of the present long, circuitous course of the Hudson river past Stony Creek, Luzerne, Corinth, and thence across the Luzerne mountain to Glens Falls, the preglacial Hudson certainly took a shorter course, most likely through the channel from Warrensburg to Caldwell and thence to Glens Falls.

The great gorge of the Hudson above Stony Creek station is surely of either interglacial or postglacial origin and in its stead a preglacial divide was located there. Evidences favoring this view are given in the paper above cited.

Since the preglacial Hudson river did not flow southward across the Luzerne sheet, it must have flowed eastward across the low mountain ridge between Warrensburg and the Lake George depression. There are but two possible channels there, namely: the Warrensburg-Hillview channel and the Warrensburg-Caldwell channel. In the paper above cited, arguments are presented to show that the latter channel was the more likely one. The preglacial Hudson was joined by the Schroon just east of Warrensburg, while a short tributary, having its source on the Stony Creek divide, flowed northward into the Hudson. An important preglacial stream, called the Luzerne river by the writer, had its source on the Stony Creek divide and flowed southward past Luzerne and Corinth and through the broad valley west of Saratoga Springs.

[1] Preglacial Course of the Upper Hudson River. Geol. Soc. Amer. Bul. 1911, 22: 177–86.

SUMMARY OF GEOLOGICAL HISTORY

A brief outline of the geological history of the portion of the Adirondacks covered by the North Creek sheet is here given in order to bring together the principal events of that history in the regular order of their occurrence so far as known.

The oldest known records of the region are written in the Grenville rocks which, by their very character and composition, are undoubted metamorphosed sediments. Because of the great thickness and widespread distribution of these strata in New York and Canada, we know they were deposited in an extensive ocean and that the length of time required for this sedimentation must have been at least some millions of years. While it is as yet impossible definitely to classify the Grenville with either the Archean or Algonkian (Proterozoic), the evidence is decidedly against its late Precambric age.

After the deposition of the Grenville sediments, the whole Adirondack region, including the area of the North Creek sheet, was elevated well above sea level. At this time the Grenville strata were probably folded. Great masses of molten rock, now represented by the syenite, granite, and granite porphyry, were intruded just before, during, or after the uplift, the most reasonable view being that the intrusion occurred during the uplift because the same great pressure could well have pushed up the molten masses during the process of elevation. In some cases the Grenville appears to have been pushed upward and to have been largely removed by erosion since; in other cases the Grenville was more or less engulfed by, or involved with, the molten flood as shown by the numerous Grenville inclusions and the areas of mixed gneisses; while in still other cases the Grenville rocks were left practically intact as shown by the large Grenville areas. These intrusives now exposed at the surface were, at the time of their intrusion, deeply buried under a great thickness of overlying rock material. This we know because they are true plutonic rocks which could have cooled only under such conditions. The vast amount of erosion since their intrusion has exposed them.

Following this great period of igneous intrusion there was a time of minor igneous activity when the gabbros, in molten condition, were forced upward into the crust of the earth. Since the gabbros now exposed at the surface are true plutonic rocks they too must have been deeply buried under material which has been removed by erosion.

After the intrusions the whole region was subjected to intense compression and metamorphism when the gneissic or foliated structure of all the rocks so far mentioned was developed. This structure is now shown in the rocks at the earth's surface; but, since such a structure can develop only in rock masses which are deeply buried, we know that at the time of the compression the present surface rocks were deeply covered.

The rocks represented by the coarse grained pegmatite dikes of the quadrangle were intruded after this period of intense compression because they lack the gneissic structure, and before the diabase because the latter rock cuts the pegmatite.

The great elevation of the region, above referred to, inaugurated a long period of erosion to be measured by at least some millions of years, and extending into the early Paleozoic era.

After the removal, by erosion, of some thousands of feet of rock materials, the last igneous activity of the region occurred when the molten diabase was forced through narrow fissures in the earth to cool in the form of dikes. The utter lack of metamorphism and the fact that they cut all the other rocks show that this diabase is the youngest of the intrusives. That it must have cooled rather close to the earth's surface is evidenced by the fine grained to even glassy texture.

As a result of the vast erosion, the whole area was worn down to near sea level and presented only a moderate relief. Then a gradual sinking took place when the sea steadily encroached upon the old land from the east, and the early Paleozoic sediments were deposited upon the old land surface. As the nearby outliers show, the first sediment to cover the area of the quadrangle was the upper Cambric (Potsdam) sandstone, followed in turn by the Theresa passage beds and the Little Falls dolomite which are also of Cambric age.

Recent studies have shown that, toward the close of the Cambric, there was a gentle upward movement of the Adirondack region to above sea level after which some erosion took place. Then, early in the Ordovicic period, the Champlain and Mohawk valley regions sank below the ocean surface when the thick limestones and shales of that period were laid down. It is highly probable that the North Creek area was also submerged under the Ordovicic sea, though positive evidence is lacking. At any rate we have no reason to think that this area, or in fact any of the Adirondack region outside of the immediate Champlain and St Lawrence valleys, was ever again below sea level after the Ordovicic period.

Thus it is more than probable that northern New York underwent erosion during all of the late Paleozoic era and certainly during the Mesozoic era, when an immense amount of Paleozoic sediment and some Precambric rock were stripped off by erosion. By the close of the Mesozoic northern New York was reduced to the condition of a fairly good peneplain with some hard rock masses rising to moderate heights above the general level.

At the close of the Mesozoic, or the beginning of the Cenozoic era, the great peneplain was upraised and a new period of active erosion was inaugurated to continue to the present time.

Much of the faulting of the area dates from the time of this peneplain uplift or even later, though it is likely that some dates from toward the close of the Paleozoic era at the time of the great Appalachian revolution.

Immediately preceding and probably during much of the great Ice age this region, like all the northeastern United States, was considerably higher than now as proved by such drowned river channels as those of the lower Hudson and St Lawrence.

During the Ice age of the Quaternary period, the area of the quadrangle, in common with all New York State, was buried under a great ice sheet which has left many records such as striae, glacial boulders, moraines, and drift deposits in general. The preglacial topography was not profoundly altered by ice erosion and deposition. The many extinct and existing lakes of the quadrangle were formed either by the actual presence of the ice dam itself or, more commonly, by irregular deposits of drift across old stream channels.

A subsidence of the land several hundred feet below the present level took place toward the closing stages of the Ice age or immediately after it for this latitude, when arms of the sea extended through the Champlain and St Lawrence valleys.

The most recent movement of the land has been a differential uplift with greater elevation toward the north. At the latitude of the North Creek sheet, this postglacial uplift has amounted to a few hundred feet, the differential character of the uplift being shown by the tilting of certain of the extinct glacial lake deposits.

ECONOMIC GEOLOGY

GARNET

At the time of the field work but one garnet mine was in actual operation within the map limits, but in all there are at least five localities where more or less garnet mining has been carried on as follows: (1) near the top of Oven mountain; (2) one-half of a mile southeast of Holcombville (Rexford's mine); (3) in the mixed gneiss area just south of Daggett pond (Elisha Parker farm); (4) near the mouth of Mill creek (Sanders Brothers mine now in operation); and (5) three-fourths of a mile east of Fuller pond. Besides these the principal garnet mines of the Adirondack region lie in the northern portion of the adjoining Thirteenth lake sheet. One of these is the Rogers (Barton) mine near the top of Gore mountain and the other is the Hooper mine on the west side of Thirteenth lake. In all cases open pit methods of mining are employed.

The Oven mountain mine has not been worked for nearly twenty years, and at no time was a crushing plant operated. After blasting out the garnet-bearing rock and reducing it in size by means of sledge hammers, the large garnets were picked out by hand. The mode of occurrence is of unusual interest. The matrix, or rock carrying the garnets, is a gray, medium grained, feldspar, hornblende, biotite, gneiss, a thin section showing 20 per cent orthoclase; 25 per cent oligoclase to labradorite; 50 per cent hornblende; 2 per cent biotite; 2 per cent magnetite; together with a little pyrite, zoisite, and apatite. Imbedded in this gray matrix are numerous, well-scattered, translucent, pale reddish brown garnets ranging in size up to several inches. These garnets are always quite well granulated and never show crystal outlines. Each garnet is completely inclosed within an envelop of pure, black, medium grained hornblende crystals. Occasionally a half-inch, irregular shaped crystalline mass of acid plagioclase or biotite may lie just between the garnet and the hornblende rim. These reddish garnets completely surrounded by rims of black hornblende, which are in turn imbedded in the gray gneiss matrix, present a very striking appearance. As shown on the geologic map, this garnet-bearing rock occurs as a long, narrow inclusion of Grenville gneiss within the Oven mountain granite.

At the Rexford mine there are several large openings but none have been worked for about fifteen years. The mode of occurrence is almost exactly like that in Oven mountain, only here there appear to be several (smaller) inclusions of the garnet-bearing hornblende gneiss instead of one, and the country rock is a very gneissoid syenite. Garnets up to 5 inches across and always with hornblende rims occur here.

By way of comparison with the Oven mountain and Rexford mines, the Rogers mine on Gore mountain should be mentioned as of exactly the same type of occurrence but with garnets generally much larger, those of 5 or 6 inches in diameter being very common and the largest ones taken out are said to have been nearly the size of a bushel basket. As a rule the hornblende rims increase in width with the size of the garnets, and the large garnets imbedded in the walls of this mine present a most interesting appearance. The garnet-bearing hornblende gneiss here forms an inclusion in syenite fully three-fourths of a mile long and 200 feet wide. Several large openings have been made in this rock.

At the old mine on the Parker farm the rocks are a mixture of granitic syenite and Grenville interbanded parallel to the strike of the foliation. These bands of rock are often 20 to 40 feet wide, one of them being made up of a nearly pure, granular, medium grained mass of irregular crystals of reddish brown garnet and bright green pyroxene (coccolite?). About twenty years ago this band of garnet rock was mined, crushed, and put into barrels, there being no attempt to separate the pyroxene from the garnet.

At the Sanders Brothers mine the mode of occurrence is very similar to that of the Parker mine, the bands of Grenville being, however, somewhat less pronounced and numerous. The rock which is mined is quite badly granulated, and consists mostly of intimately associated reddish brown garnet and green pyroxene (coccolite?) in small grains, with sometimes a little feldspar. There are some streaks or patches of nearly pure garnet. Work began in 1907 on the south side of the creek but now all the mining is confined to the north side (see map). The garnet, pyroxene rock is crushed, put into bags, and shipped to various parts of the world.

Years ago an attempt was made to mine the garnets which occur in the coarse, feldspar, biotite, quartz, garnet (Grenville) gneiss about three-fourths of a mile east of Fuller pond.

At the Hooper mine, near Thirteenth lake, the garnets occur as crystals, often with good crystal boundaries, up to an inch or more in diameter. They are thickly scattered through a medium to fairly coarse-grained, dark to light gray, very gneissoid hornblendic rock which has the composition of a basic syenite or acidic diorite. These garnets never show the rims of hornblende. This type of occurrence has not been noted on a large scale within the map limits of the North Creek sheet, though a rock almost exactly like it does occur at the Rogers mine as a distinct zone (wall rock) intermediate in position and composition between the typical garnet gneiss and the country rock of syenite, where the garnet rock grades perfectly into the syenite.

All modes of occurrence of garnets observed by the writer on the North Creek and Thirteenth lake sheets may be summarized as follows: (1) as crystals or grains in various Grenville rocks, as the garnet-pyroxene gneisses, the dark hornblende-garnet gneiss, the gray feldspar-biotite-garnet gneisses or schists, and the white or very light gray feldspar gneisses; (2) as distinct crystals frequently occurring in all types of intrusive rocks — syenite, granite, granite porphyry, and gabbro — except the diabase; (3) as large more or less rounded masses, with distinct hornblende rims, in the long, lenslike inclusions of Grenville hornblende gneiss in syenite or granite; and (4) as more or less distinct crystals, without hornblende rims, in a certain special basic syenitelike or acidic dioritelike rock.

In case no. 1 (for example Sanders Brothers and Parker mines) the garnets have, in the usual way, crystallized out of masses of sediments under conditions of thermal and dynamic metamorphism.

In case no. 2 the garnets appear mostly to have crystallized out of the original magmas, their presence possibly being due to some assimilation of Grenville sediments, though this is by no means proved. Sometimes, as in the gabbros, the garnets may have been produced secondarily after the cooling of the igneous masses.

Case no. 3 (for example, Oven mountain, Rexford, and Rogers mines) is of particular interest because of the very large garnets surrounded by reaction rims. Without question the garnets occur in lenses of Grenville sediment which were caught up or included in the great igneous masses at the time of their intrusion, the tremendous heat and pressure being especially favorable for a very complete rearrangement and crystallization of the masses of sediment which were rather low in silica. The hornblende rims or envelops are quite certainly great reaction rims around the garnets, but just at what stage of the metamorphism they were produced is not at all clear to the writer. The rounded and granulated condition of the garnets suggest that the reaction rims of hornblende may have formed some time after the crystallization of the garnets and possibly at the time when the great pressure producing the foliation was brought to bear.

A clew to the origin of the garnets in case no. 4 (for example, Hooper's mine) is furnished by a study of the wall rock in the mine on Gore mountain. The typical garnet-bearing rock of the mine passes by perfect gradations through an 8 or 10 foot zone into a basic (quartzless) syenite which contains garnet crystals up to an inch or more across but never with hornblende rims, and this rock in turn grades into the typical country rock of syenite which is somewhat garnetiferous. The writer is fully convinced that this transition zone (wall rock) has been formed by the assimilation or actual melting or fusing together of the syenite and the border of the great inclusion at the time of the intrusion of the syenite. In hand specimens and in thin sections, as shown in the field, the garnet rock at the Hooper mine is almost exactly like this wall or transition rock of the Rogers mine and it also appears to grade into the country rock. In the Hooper mine this transition rock makes up practically the whole mass of rock which is mined and is hence much more extensive than at the Rogers mine. All evidence strongly points to the origin of the Hooper mine rock as due to rather thorough melting together of an admixture of syenite and Grenville hornblende gneiss where the Grenville inclusion was perhaps deeper down in the magma and hence subjected to much greater heat, or possibly a number of smaller hornblende gneiss inclusions were assimilated by the molten syenite or granite.

GRAPHITE

Within the map limits but one graphite mine has ever been in actual operation, though prospect holes have been made at various places. The mine, including an open pit and short tunnel and separating mill, is located 1 mile southwest of Johnsburg. The graphite occurs in small flakes in gray, thin to thick bedded, Grenville gneisses which are usually very rich in quartz. A detailed description of specimens from this mine has been given on page 14. Some graphitic limestone was taken out from near the mine entrance. The rocks strike north 70° east and dip 35° to the south. This mine was worked as late as June 1910 but apparently has not been very successful. An interesting feature is a quartz vein up to a foot wide, which cuts across the graphitic beds at a high angle and which contains rich seams (as much as an inch wide) of pure graphite. The mine superintendent stated that in 1899 one piece of graphite weighing 543 pounds was taken out. Excellent specimens of associated quartz and graphite may be obtained from the mine dumps.

A prospect hole 2½ miles due south of Pottersville and close to the road was opened in limestone some years ago. Some of the limestone beds are pyroxenic to serpentinous. The limestone contains occasional flakes of graphite up to one-half of an inch across, as well as some phlogopite, pyrite, brown hornblende, and a few octahedrons of brown spinel.

One-half of a mile beyond the northern map limit and near where the road crosses Trout brook there is an old graphite mine which was not visited by the writer.

Throughout the quadrangle scattering flakes of graphite are rarely absent from the crystalline limestone, and more seldom they are found in other rocks of the sedimentary series.

MICA

The only place where mica mining has been attempted is in a large pegmatite dike, which comes against the long gabbro mass on its east side, 2¾ miles south-southeast of Chestertown. At the time of the writer's visit (1910) the mine was being worked in a small way by two or three men. While occasionally mica is present in considerable quantity, it seldom occurs in books up to 5 or 6 inches across. Muscovite mica is often associated with the pegmatite dikes but thus far no place has been discovered which could really be called a good mining proposition.

ASBESTOS

The only attempt to mine asbestos is at the locality three-fourths of a mile southeast of Thurman village. During the summer of 1910 large prospect holes had been opened up and mining machinery was being installed, though the writer does not know whether the mine is now in operation. The asbestos is of the serpentine variety, known as chrysotile, and occurs in numerous irregular veins in the greenish gray serpentine marble. Of all the veins noted in the prospect holes, the widest was less than an inch, though wider veins may since have been found. The asbestos is of good quality, but numerous fairly thick veins must be found in order to make a paying proposition of the mine.

FELDSPAR

Orthoclase feldspar is of course one of the commonest minerals in the whole region, but only where it occurs in large crystals in the pegmatite dikes is it likely ever to become of commercial importance. In all the numerous pegmatite dikes examined, the orthoclase almost invariably occurs in crystals which are too small and too intimately associated with much quartz and acid plagioclase feldspar to be worth considering as mining propositions. Perhaps the most favorable locality is the pegmatite dike lying along the west side of the gabbro dike on the mountain top 1 mile south-southeast of The Glen. A single mass of pegmatite there is about 25 feet wide and 50 feet long and very rich in orthoclase and albite crystals up to 5 or 6 inches in length, together with more or less quartz and black tourmalin. The nearness to the railroad station and the fact that an old road now extends nearly to the top of the mountain, are features favorable to mining here, but the small size of the exposed mass and the abundance of albite are unfavorable.

ROAD METAL

Rock such as that of the diabase dikes of the quadrangle is popularly known as "trap rock," and it takes rank among the finest natural road building materials because of its hardness, fineness of grain, homogeneity, and good binding power. So far not a single quarry has been opened in any of these dikes though some of them are large and well situated with respect to roads and good quarry drainage. Among such dikes are those at the west base of Heath mountain (Ingraham farm); 1½ miles north-northeast of Pottersville; and two-thirds of a mile a little south of west of Igerna. Smaller, but well located, dikes are three-fourths of a mile southeast of Kelm mountain and one-half of a mile southeast of The Glen.

The gabbro masses, especially the more basic ones, would furnish a very large amount of good road material. This rock is hard, homogeneous and rich in iron-bearing minerals to give good binding power. So far but two quarries have been opened in the gabbros and these for State road purposes. One of these quarries is in the south end of the large, coarse grained, gabbro boss on the south side of Loon lake, and the other is in the gabbro boss 1 mile west of Riverside and near the new State road.

The basic varieties of syenite, especially those free from mica and low in quartz, would also make good road metal, but no quarries have yet been opened in such rock.

The granite and granite porphyry in general are rather poor road materials because of the high quartz and mica content and the usual deficiency of iron-bearing minerals to furnish a good binder. Such rock has, however, been rather extensively quarried at three places for State road work. One of these quarries is situated two-thirds of a mile north of the north end of Loon lake and above the road; the second is along the State road 1¾ miles northeast of

Pottersville; while the third is by the State road 3¼ miles north-northeast of North Creek.

The Grenville gneisses are nearly always of poor quality for road work because of the high quartz and mica content and the heterogeneity of the rocks which are in layers of varying composition. In spite of this, one quarry for State road purposes has recently been operated near the southeastern end of Loon lake.

BUILDING STONE

There is an inexhaustible supply of building stone of excellent quality within the map limits. The syenite, granite, and granite porphyry all rank as very strong and durable building stones. Of these the granite porphyry would perhaps make the most effective and beautiful stone when highly polished because of the large, scattering, pink, feldspar crystals which are set in the much finer grained gray matrix. The color of this rock would remain practically unaltered on exposure to the weather. Some of this rock from the quarry at Horicon is said to have been used in the State Capitol at Albany. The pink granites, too, would make beautiful and very durable building stones not subject to color change. The syenites, which are generally greenish gray when fresh, would weather to light brown on exposure to the atmosphere but, as regards durability and strength, they would be excellent stones. These igneous rocks are considerably used locally but because of the distance from population centers, no quarries have been opened up for shipping purposes. The pinkish gray granite used in the construction of the new Warrensburg High School building was obtained from the south side of Hackensack mountain and just off the map.

The only stone which has been quarried for shipping purposes is the green marble or so-called verde antique of the Grenville series. Though occurring at a number of localities, the only place where quarrying has been done, and this years ago, is one-half of a mile west-southwest of Thurman village. This rock is a medium grained, white to greenish gray marble through which are scattered many streaks and blotches of bright green serpentinous material, so that the polished stone presents a striking effect.

INDEX

EDUCATION DEPARTMENT
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STATE MUSEUM

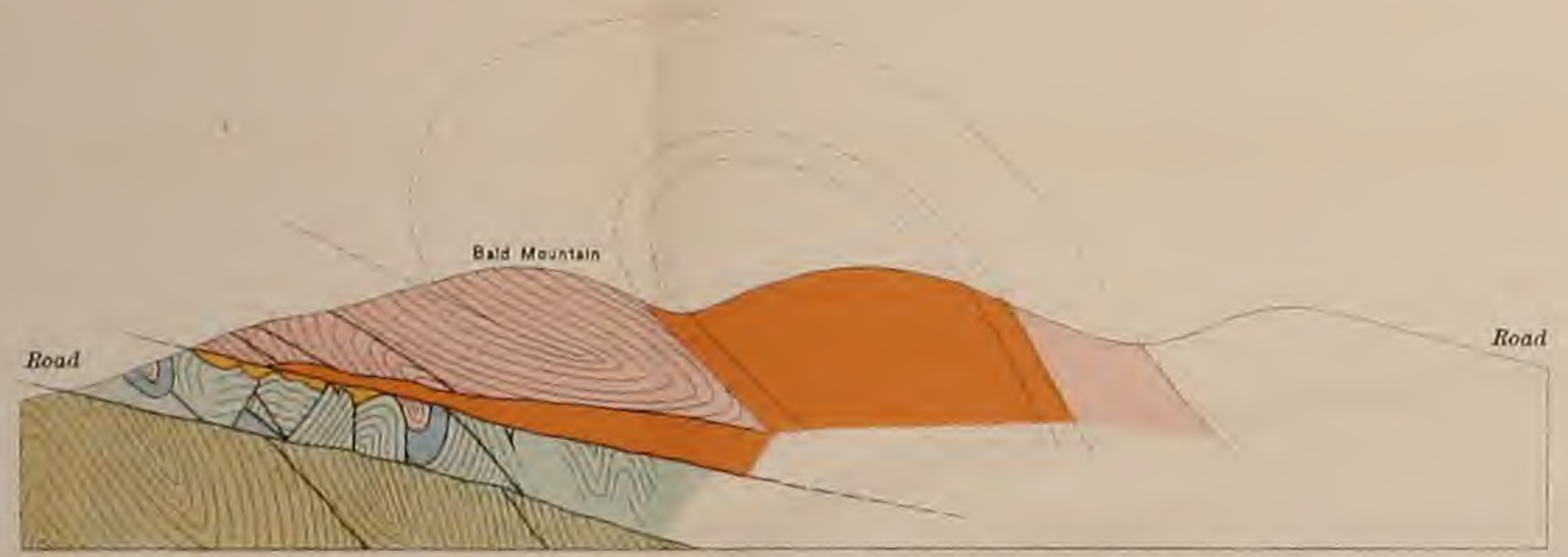
BULLETIN 169
SARATOGA-SCHUYLERVILLE QUADRANGLES

Geology Schuylerville Quadrangle, by R. Ruedemann and H. P. Cushing, 1910-1912.

Geology Saratoga Springs Quadrangle, by H. P. Cushing, R. Ruedemann and W. J. Miller 1909-1910.

SKETCH OF BALD MOUNTAIN QUARRIES

a, a. Cliffs of Rysedorph Hill conglomerate left standing.
b, b. Masses of black shale
c, c. Quarry faces (see photos).
d, d. Exposures of Bald Mountain limestone and dolomite.
x-x-x Original surface boundary of Georgian at quarry.



DIAGRAMMATIC W–E SECTION; THROUGH BALD MOUNTAIN RIDGE.

Scale: 1 mile = 4 inches; vertical scale exaggerated 2 times.

E–W SECTION; THROUGH WESTERN FOOT OF BALD MOUNTAIN.

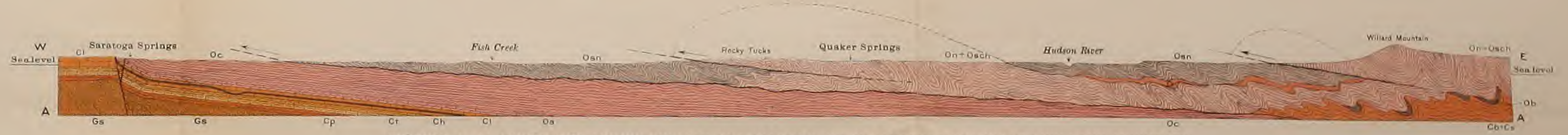
LEGEND

Mylonite.
Snake Hill shale.
Rysedorph Hill conglomerate.
Bald Mountain limestone and dolomite.
Schodack shale and limestone.
Bomoseen grit with quartzite on top.

SECTION A–A; ACROSS THE SARATOGA QUADRANGLE, FROM LAKE DESOLATION THROUGH SARATOGA SPRINGS.

Scale: 1 inch = 1 mile; vertical scale exaggerated 2½ times.

by H. P. CUSHING

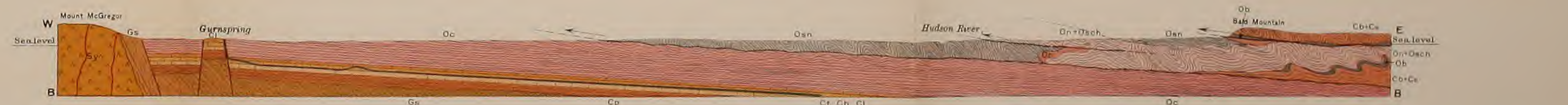


SECTION A–A; ACROSS THE SCHUYLERVILLE QUADRANGLE, FROM SARATOGA SPRINGS TO WILLARD MOUNTAIN.

Supposed course of mineral water shown by blue line.

Scale: 1 mile = 1 inch; vertical scale not exaggerated.

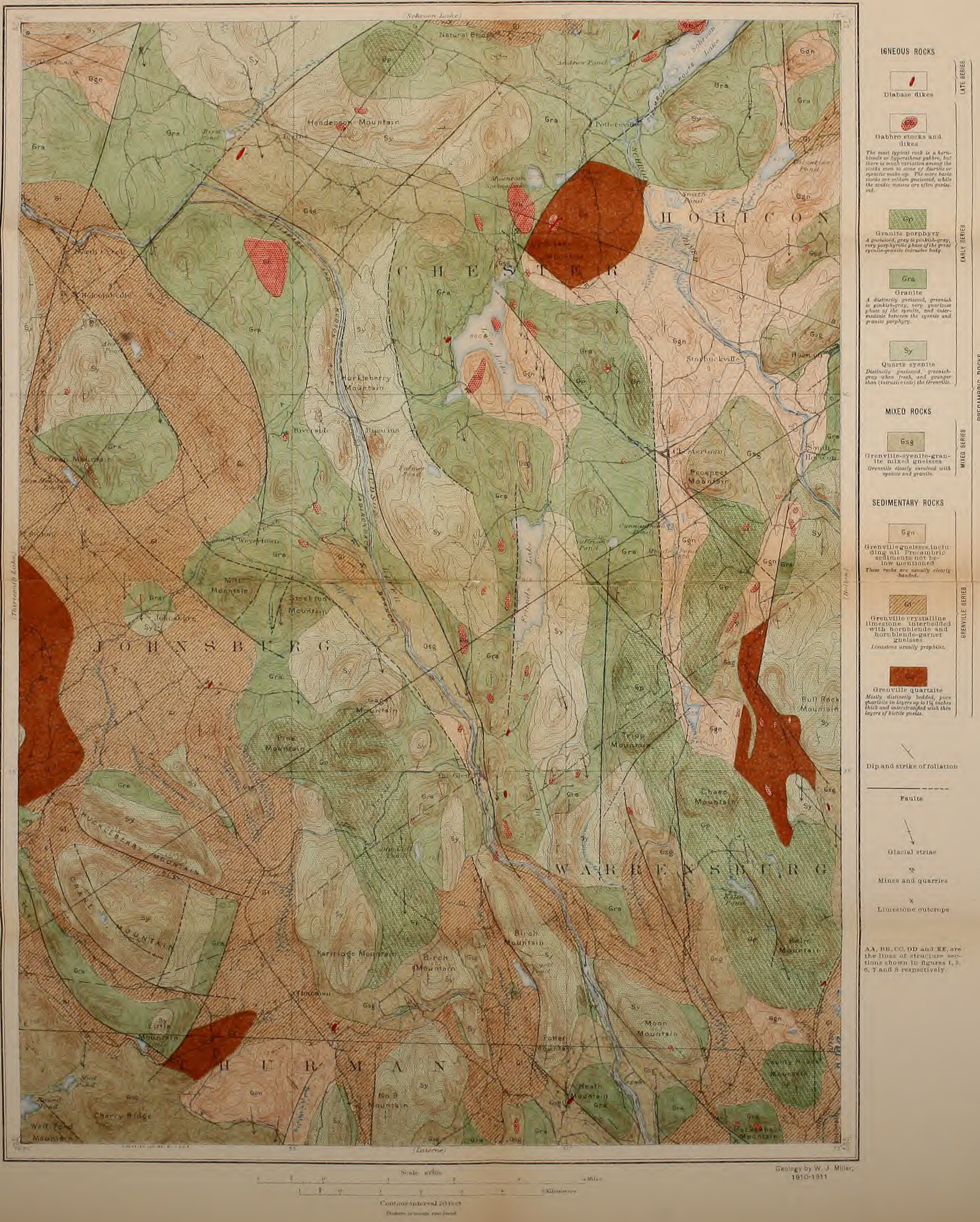
by R. RUEDEMANN



SECTION B–B; ACROSS THE SCHUYLERVILLE QUADRANGLE, FROM MOUNT McGREGOR TO BALD MOUNTAIN.

Scale: 1 mile = 1 inch; vertical scale not exaggerated.

by R. RUEDEMANN



Geology by W. J. Miller,
1910-1911