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Editor: EDWARD S. DANA.

FOURTH SERIES

VOL. XXVIII—[WHOLE NUMBER, CLXXVIII.]

WITH TWO PLATES.

NEW HAVEN, CONNECTICUT.

1909.

THE TUTTLE, MOREHOUSE & TAYLOR COMPANY,
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CONTENTS TO VOLUME XXVIII.

Number 163.

SCIENTIFIC INTELLIGENCE.

Number 164.

SCIENTIFIC INTELLIGENCE.

Number 165.

SCIENTIFIC INTELLIGENCE.

Number 166.

SCIENTIFIC INTELLIGENCE.

Number 167.

SCIENTIFIC INTELLIGENCE.

Number 168.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. I.—*On the Magnetic Properties at High Excitations of a Remarkably Pure Specimen of Soft Norway Iron*; by B. Osgood Peirce.

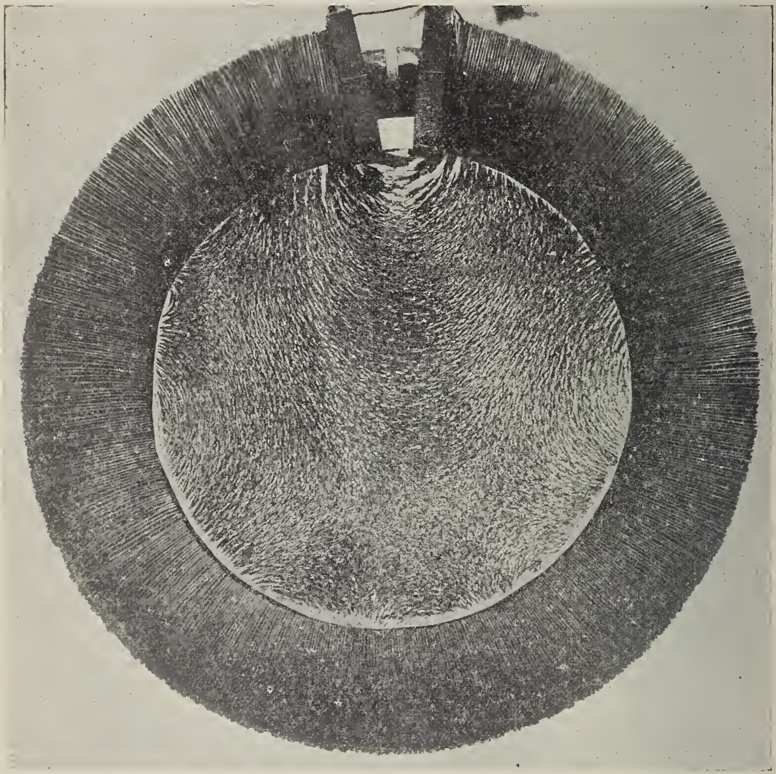
Some months ago an electro-magnet was made for special use in the Jefferson Laboratory which had the form of a toroid uniformly wound with insulated wire for nineteen-twentieths of its perimeter. The core was of stout iron rod bent into the shape of a ring—complete except for a gap one centimeter wide. The mean diameter of the core was about fifty centimeters and a meridian section of the iron had an area of about twenty square centimeters. The exciting coil was made of about thirty kilograms of No. 10 B. & S. wire and the magnet had the general appearance indicated by figure 1, although the turns of wire which show in the photograph belong to a short test coil outside the winding proper.

It is evident that, under the most favorable circumstances, the leakage in the case of a magnet of these dimensions must be very large, but when this magnet was tried its performance fell so far below what, according to any known experience, it ought to have been, that it was thought best to have the iron tested both chemically and magnetically in the hope that the information thus procured might prove valuable in future designing. This seemed the more desirable since the core had been obtained by Professor Trowbridge, the Director of the Laboratory, in response to his inquiry for the very best brand of soft Norway iron to be had in the market.

The chemical analysis made by Mr. Emile Raymond Riegel showed this commercial iron to be of an extraordinary purity. The tests for nickel, cobalt, manganese, tungsten, and for "Groups IV and V" were all negative. There was less than 0·03 per cent of carbon, less than 0·047 per cent of phosphorus, less than 0·03 per cent of silicon, and less than 0·003 per cent of sulphur. The iron dissolved violently in slightly diluted HNO_3, and when the residue had been dissolved for carbon, a mere discoloration of the beaker remained.

There was nothing, therefore, in the composition of the iron core to account for the comparative uselessness of the magnet.

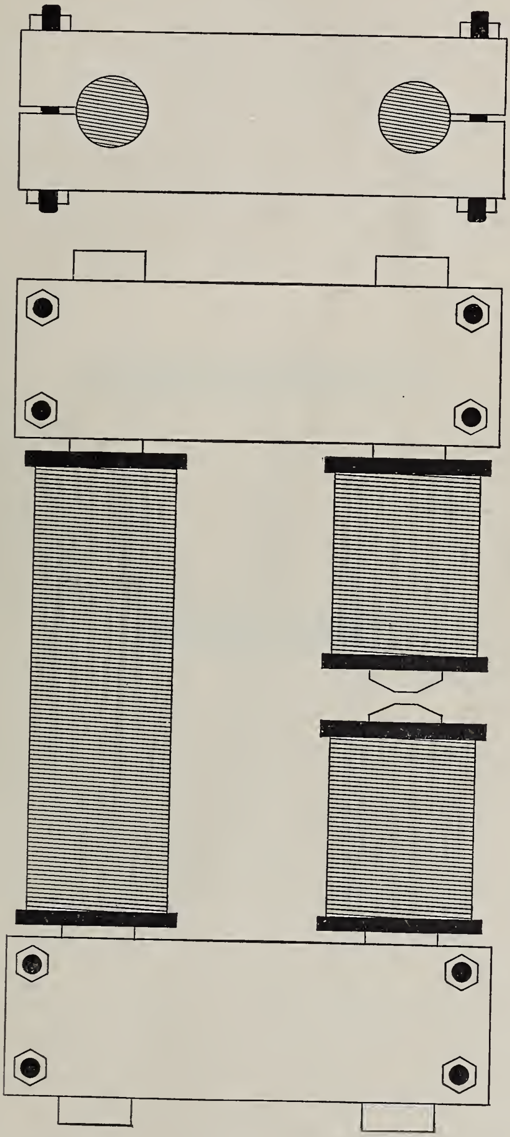
Fig. 1.



The response of this remarkable iron to magnetic excitation was equally satisfactory, and the present report describes briefly determinations of the permeabilities of two pieces of it under very strong magnetizing fields. The work was done by Mr. John Coulson and myself, and was extremely troublesome because only a short stout piece of the iron used in making the core was available. From this a rod 1·26 centimeters in diameter and about 30 centimeters long was turned by Mr.

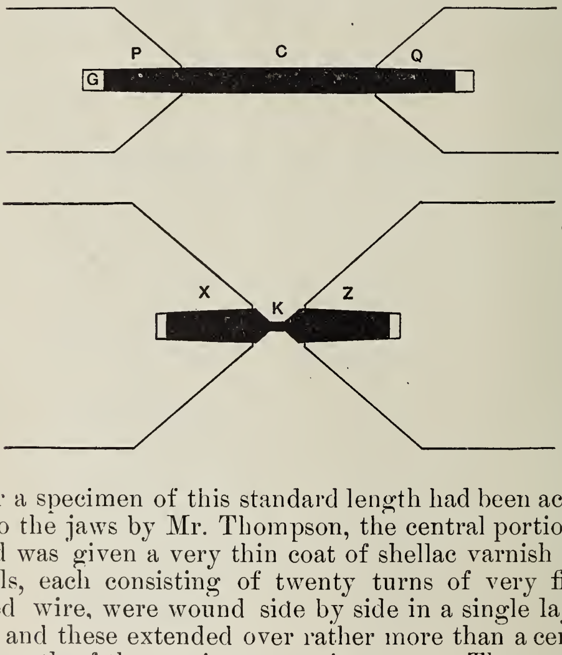
G. W. Thompson, the mechanician of the Jefferson Laboratory, and this rod was tested in various ways in the yoke rep-

Fig. 2.



resented in figure 2. Jaws of various shapes were tried and different ways of making the joints between the jaws and the test piece. Usually under strong magnetic excitation, between the jaws of the yoke, there was a sensible leakage of lines of induction through the surface of the specimen into the air, and the field in the air about the rod was far from uniform in any available portion. We found eventually, however, that if a piece of the rod of about 80 millimeters free length, with tapered ends, was inserted into holes in the ends of the conical jaws represented in figure 3, the lines of force in the air just about the specimen near its center were for a considerable distance practically parallel to the axis of the rod and that the value of H in the air in this region was sensibly equal to the value of the same quantity in the rod.

Fig. 3.



After a specimen of this standard length had been accurately fitted to the jaws by Mr. Thompson, the central portion of the iron rod was given a very thin coat of shellac varnish and two test coils, each consisting of twenty turns of very fine well insulated wire, were wound side by side in a single layer over the rod and these extended over rather more than a centimeter of the length of the specimen near its center. These coils were first tested against each other to find out whether they were practically alike, and then—if this condition was satisfied—both together in series formed the inner test coil (K). The outer test coil (L) was wound in a single layer on a very thin shell of boxwood which had been seasoning for many years. After corrections had been made for the thickness of the wire of the test coils and of its insulation, it was possible .to compute from the measured change of induction flux through

K and L due to a reversal of the current in the exciting circuit of the yoke, corresponding values of H and B.

The ballistic galvanometer used in this work had a period so long that no appreciable error was caused by the fact that several seconds were necessary to bring about a complete reversal of magnetization in the magnetic circuit. The galvanometer has been described under the letter V, in the Proceedings of the American Academy of Sciences in December of last year.

The test coils were wound by Mr. Coulson, who has helped in all the work.

The iron of which the magnet core described above was made is here denoted by the letter P, while Q denotes a similar very pure specimen of Norway iron obtained from a new source.

TABLE I.—*Specimen of Norway Iron (P) Magnetized in Massive Yoke.*

(Free length about 80 millimeters, diameter 12·67 millimeters.)

H	B	I
150	19160	1513
200	19920	1566
300	21040	1650
400	21660	1692
500	21920	1705
600	22130	1713
700	22300	1720
800	22450	1723
1000	22720	1729
1200	22940	1730
1400	23180	1731
1600	23380	1732
2000	23780	1733
2500	24280	1733

The maximum value of I seems to be in the vicinity of 1733, and for large values of the excitation corresponding values of H and B may be computed by means of the equation $B=H+21780$.

This record shows conclusively that the magnetic permeability of this iron under strong excitation is extraordinarily high and that the failure of the magnet mentioned at the beginning of this report was not due to poor material in the core. The real source of the difficulty is disclosed by an examination of the diagram shown in figure 4. This was obtained by sprinkling iron filings upon a horizontal piece of cardboard which rested on the toroid as it lay upon the floor and carried a heavy current. Although the cardboard was not favorably placed, there are evidences that at least ten consequent poles were created between the ends of the core when it was strongly excited. When the exciting current was reversed these poles changed sign, but in many places outside the exciting coil the direction of the field was always opposed to what it would be if these consequent poles did not exist. This core has been annealed as well as the maker could do it, after it had been bent into shape, but the process demands great skill and, as is well known, soft Norway iron is very likely to acquire slight differences of temper due to unequal heating in the forge fire.

Fig. 4.

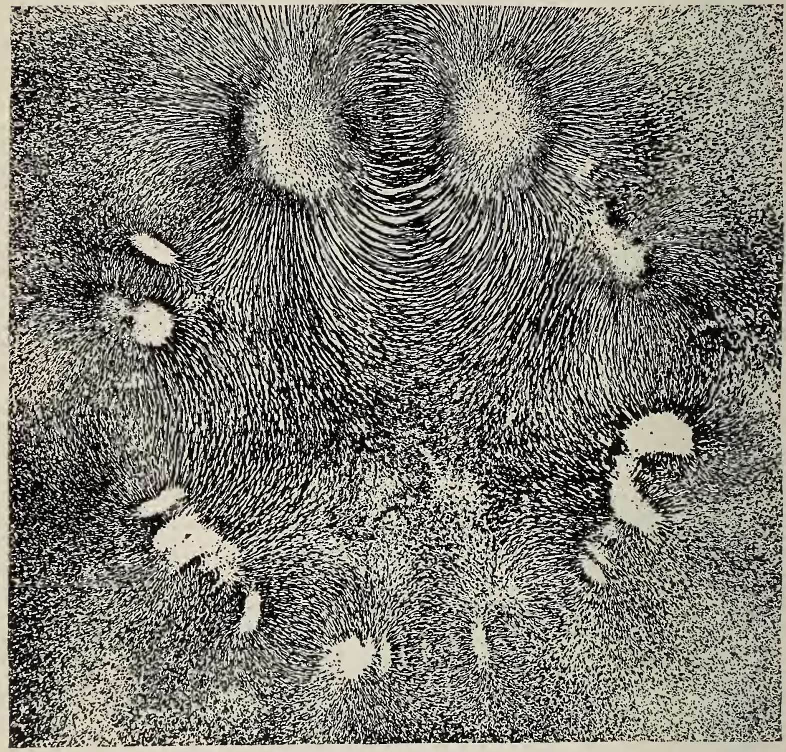


Table II exhibits the results of some observations made upon a half-inch rod of Norway iron (R), when magnetized in a uniformly wound solenoid. The rod was about ten feet long. When it was purchased this iron was very soft as is shown by the numbers in the second column, which give the values of the induction (B) corresponding to the values of H in the first column. When, however, the rod had been again subjected by Mr. Thompson to an elaborate annealing process, its permeability had been somewhat increased as appears from the values of B exhibited in the third column.

TABLE II.—*Norway Iron Rod (R) Magnetized in the Long Solenoid.*

(Length about 300 centimeters, diameter 12·67 millimeters.)

H	B (Before the iron had been annealed.)	B (After the rod had been annealed.)
5	12400	12560
10	14800	14940
14	15460	15540
20	15960	16040
30	16400	16520
40	16650	16920
50	16920	17220
60	17180	17450
70	17400	17630
80	17600	17820
100	17940	18210

Specimen Q, like specimen P, was cut from a bar of the best Norway iron two inches in diameter, but the two bars came from different dealers. These irons seem to be nearly alike in temper and in composition.

TABLE III.—*Specimen of Norway Iron (Q) Magnetized in Massive Yoke.*

(Free length about 80 millimeters, diameter 12·67 millimeters.)

H	B	I
300	20530	1610
400	21110	1648
600	22020	1704
700	22300	1719
800	22510	1728
1000	22800	1735
1200	23020	1737
1400	23240	1738
1650	24240	1738
2000	23840	1738
2400	23490	1738

From $H=1100$ up to $H=2450$, the observed values of I differ on the average from their mean by about one-sixth of one per cent only.

For high excitations, corresponding values of H and B may be obtained from the equation $B=H+21840$.

Table IV shows the results of some determinations of the maximum value of I made upon an isthmus piece of the iron P after it had been subjected to an annealing process lasting about 48 hours and was therefore extremely soft.

TABLE IV.—*Specially Annealed Isthmus Piece of Norway Iron* (*P*).

(Cross section of isthmus 0·2050 square centimeters; mean area of inner test coil 0·2230 square centimeters; mean area of outer test coil 0·5025 square centimeters.)

Exciting Current	H	B	I
1·00	5920	28580	1799
4·07	12370	34900	1794
5·58	13720	36210	1790
9·90	16000	38530	1793
23·00	18130	40780	1802
31·00	18810	41400	1797

For a current of about 55 amperes a value $B=42200$ was reached but the current fell so rapidly that H could not be accurately determined. In this case the excitation was upwards of 160,000 ampere-turns.

It is interesting to compare this remarkable value for the maximum intensity of magnetization with that obtained for a specimen of the iron R, after it had been thoroughly annealed.

TABLE V.—*Annealed Norway Iron* (*R*) *in Massive Yoke.*

(Free length about 80 millimeters.)

H	B	I
800	22770	1748
900	22880	1749
1000	23000	1750
1500	23500	1751
1800	23810	1751
2000	24010	1751
2350	24360	1751

The Jefferson Laboratory, Cambridge, Mass.

ART. II—*Notes on some Rocks from the Sawtooth Range of the Olympic Mountains, Washington;*[*] by RALPH ARNOLD.

PROBABLY less is known about the geology of the Olympic Mountains, Washington, than of any other equal and important area in the United States.[†] For that reason the writer was particularly interested in a small collection of rocks from one of the important but little known ranges of this great mountain group, recently received from Mr. F. H. Stanard, Seattle, Washington. The following paper is based upon the examination of these rocks supplemented by brief field notes supplied by Mr. Stanard. The writer is indebted to Dr. Albert Johnannsen, United States Geological Survey, for assistance in the petrographic determinations.

Location.

The Sawtooth Range is a narrow, pinnacled ridge about 15 miles in length, extending in a southwest-northeast direction in the southeastern part of the Olympics 45 miles due west of Seattle. Mt. Skokomish, elevation 6500 feet, in Sec. 3, T. 24 N., R. 5 W., and Mt. Henderson, a mile farther northeast, are the highest points in the range and are located between one-third and one-half the distance from the southwest to the northeast end. The southern end of the Sawtooth Range is 6 miles in an air line from Lake Cushman, but by trail is at least twice as far. Some of the rocks discussed come from near what is known as Camp Black and White[‡] in Sec. 7, T. 24 N., R. 5 W., midway between the crest of the south end of the range and Box Canyon, through which flows the North Fork of the Skokomish River. Still others come from Smith's

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[*] Published with the permission of the Director, U. S. Geological Survey.

[†] The following are the most important articles so far published concerning the region: S. C. Gilman, The Olympic Country, Nat. Geog. Mag., vol. vii, pp. 133–140, pl. 16, 1896; Arthur Dodwell and Theodore F. Rixon, Forest Conditions in the Olympic Forest Reserve, Washington, Prof. Paper, U. S. Geol. Survey, No. 7, 100 pages, 20 plates, 1 map, 1902; H. S. Conard, The Olympic Peninsula, Washington, Science, N. S., vol. xxi, No. 532, March 10, 1905, pp. 392–393; Ralph Arnold, Geological Reconnaissance of the coast of the Olympic Peninsula, Washington, Bull. Geol. Soc. Amer., vol. xvii, pp. 451–468, pls. 55–58, Sept. 1906; Chas. E. Weaver, Notes on the Bedrock Geology of the Olympic Peninsula, The Mountaineer, vol. i, No. 3, Sept. 1907, pp. 57–64, 1 plate, Seattle, Wash.

[‡] It is always interesting to know the derivation of place names, and in this connection Mr. Stanard furnishes the following note concerning the origin of "Camp Black and White": "This camp was named by some of the early elk hunters from a brand of whiskey of that name, one of the party being sober enough at one period of their sojourn at this place to mark the name prominently on a tree."

Camp between 1 and 2 miles southeast of Camp Black and White, and a few others from the region adjoining the camps.

General Geology.

According to Mr. Stanard, the crest of the southwest end of the ridge is composed of a coarse conglomerate striking parallel with the range. The conglomerate has been subjected to severe crushing and faulting, and quartz veins are not uncommon in it. The rest of the country rock consists of alternating hard sandstone, shale and slate, striking north and south and usually standing vertical. These rocks have been much fractured and faulted and intruded by dikes of basic igneous rocks which locally have produced garnetiferous and other schists. Quartz veins carrying copper ores in commercial quantities occur along the contact between some of these igneous dikes and the intruded sedimentaries. The rocks adjacent to the veins are also usually more or less mineralized. The age of the rocks is unknown, but they may be a part of the series of conglomerate, quartzite, diabase and serpentine that is exposed on the coast between Cape Flattery and Grays Harbor at the western end of the Olympics, and which has been described by the writer* as of supposed pre-Cretaceous age. The occurrence of these similar series of rocks at both the eastern and western ends of the Olympics leads to the conclusion that the older formations, at least, are dominated by east and west strikes, and, therefore, that the Olympic Mountains, geologically speaking, must be considered as an east-west range instead of a quaquaversal.

Sedimentary Rocks.

The country rock of the northwestern flank of the Sawtooth Range consists of hard semi-metamorphosed sandstone and shale occurring in alternating beds from a few inches to many feet in thickness. These rocks stand practically vertical and have in general a north and south or northeast-southwest strike.

The sandstone, which might properly be called indurated arkose but hardly a quartzite, is fine-grained and in color dark gray, and fractures with a rough surface. The rock is traversed by at least one system of parallel joint planes, in addition to cleavage parallel to the bedding. Numerous small mica flakes glisten on the surface in reflected light. In thin slides the rock is seen to consist very largely of cherty quartz grains, a little plagioclase feldspar and numerous flakes of brown and white mica, mostly the latter.

The hardened shale, or slate, as it is more commonly called, is nearly black, cleaves quite easily and exhibits iridescent

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* Bull. Geol. Soc. Amer., vol. xvii, p. 459.

films, probably of manganese oxide, on the cleavage surfaces. A small fragment of a fossil resembling *Dentalium* was noticed in one specimen of slate and indicates the marine origin of the formation.

Metamorphosed Sedimentary Rocks.

The metamorphosed sedimentary rocks consist of garnetiferous amphibolite schist, black schist, chert and jasper. They are confined to narrow zones adjacent to the igneous intrusions, and are probably of contact origin.

The garnetiferous amphibolite schist occurs intermittently near the igneous dikes and is believed to represent a more advanced stage of metamorphism than the black schists more commonly associated with the igneous rocks of the region. The garnetiferous rock is light greenish to drab in color, shows the planes of schistosity distinctly and fractures with an undulating surface parallel with the cleavage and with knife-like edges in other directions. The specimen examined contains numerous small pyrite crystals, mostly arranged in thin layers parallel with the planes of schistosity; small garnets, though present, are not a common constituent of the schist. Judging by the general appearance of the specimen, the metamorphism of the rock was only partially completed.

One wall of some of the mineralized veins of the region consists of hardened bluish black schist, usually about 10 feet in thickness, which has been only partially metamorphosed and which grades to black slate and shale in a direction away from the igneous contact. This schist is fine-grained, and exhibits irregular crinkled cleavage faces. It fractures with sharp edges across the planes of cleavage. In thin sections it is seen to be composed of lens-shaped aggregations of quartz surrounded by small parallel stringers of opacite. Mineralization with pyrite often takes place in thin bands parallel with the cleavage, especially near the contact veins.

The only specimens of chert received came from the Black Trail claim, about 2 miles west of Mt. Skokomish, where it forms the wall of a quartz vein. It is very hard and fine-grained, black to dark reddish in color, and fractures along innumerable joint planes. The chert is usually rich in iron, and sometimes contains enough lime to render the rock softer than typical chert. Numerous small quartz veins cut the chert, usually occupying joint cracks. An impure dark greenish calcareous shale, approaching chert, occurs in the same locality as the rock just described. It is seamed with calcite veins carrying chalcopyrite, which stains the adjacent calcite green.

A light greenish drab impure limestone mottled with reddish blotches occurs in layers 2 or 3 feet thick interbedded with the chert in one wall of the vein on the east flank of Mt. Henderson. The surface of this rock weathers into minute pits so characteristic of certain limestones. The red blotches in the rock are said to sometimes carry small particles of native copper.

A specimen of material said to occur as float in the region of Copper Mountain, 6 miles south of Mt. Skokomish, consists of mineralized red jasper and gray quartz.

Igneous Rocks.

The igneous rocks in the collection embrace typical diabase, a fine-grained diabase, and a peculiar fibrous serpentine resembling antigorite. The igneous rocks are all younger than the sedimentaries, occurring as dikes intruding the latter, usually with a north to northeast trend, parallel with the strike of the sedimentaries.

The most typical example of diabase occurs as a large dike at Smith's Camp, and lies adjacent to a dark slate spotted with aggregations of white quartz. The diabase is moderately fine-grained, greenish to greenish gray in color, and breaks with a rough irregular surface. Thin veins of chlorite occur in some of the joint cracks. Under the microscope, the rock shows typical ophitic texture. Plagioclase and augite are the most important minerals, the former predominating. The plagioclase occurs in lath-shaped crystals; the augite is slightly pleochroic, and is altered in many cases. Titaniferous magnetite is found abundantly in isolated grains. Calcite is one of the alteration products. This diabase is a rock that could properly be called a greenstone.

Diabase also occurs abundantly, intruding the slates, on the west side of Box Canyon, where it has been prospected considerably, but with negative results. This rock is fine-grained, light greenish to greenish gray and breaks with a rough fracture. Pyrites are plainly visible in small but numerous specks throughout it. In thin sections, it is seen to be less typically ophitic in texture than the diabase last described. It contains about equal quantities of plagioclase and augite, the latter more pleochroic than in the diabase previously mentioned; quantities of titaniferous magnetite and iron pyrites also occur throughout the mass. Chlorite appears to be the principal product of alteration.

A specimen of a fine-grained diabase, approaching a basalt in appearance, occurs as one of the igneous rocks at Camp Black and White. In hand specimens, it is fine-grained, very dark colored and breaks with knife-like edges along several irregular systems of joint planes, parallel with which are sometimes thin chlorite veins. Fresh surfaces are rough or finely corrugated. In thin slides, the rock is seen to have fine diabasic texture, the plagioclase, which occurs in small lath-shaped crystals, apparently being more important than the augite, which in many instances is altered to chlorite. Small chlorite veins filled with segregations of calcite and calcite masses occur sparingly throughout the rock. No olivine is seen in the rock although its general appearance is like many olivine-bearing basalts.

A specimen of amygdaloidal basalt, said to have come from a detached bowlder at Smith's Camp, exhibits cavities up to 1/16 inch (2^{mm}) in diameter, filled with a soft white mineral, probably natrolite or a related mineral. This rock has been erroneously called "bird's-eye porphyry" by the prospectors.

Serpentine.—A peculiar fine-grained fibrous serpentine, probably antigorite, occurs in the igneous area at Camp Black and White. This rock is rather dark grayish green in color and upon close examination exhibits segregations of a grayer shade. It breaks along several systems of shearing planes, producing a jagged surface. Chlorite associated with a white mineral occurs abundantly in irregular veins following the fracture planes. The most interesting feature of the rock disclosed by a miscroscopic examination is the occurrence in it of numerous skeleton crystals of olivine now entirely altered to chlorite. Most of these skeletons appear as long narrow rectangles with an acute, deep reëntrant angle in each end. There are also a few better developed olivine crystals mostly altered to calcite. Radiating bunches of a serpentine-like mineral, probably antigorite, form the groundmass.

Ores.

The ore samples submitted by Mr. Stanard include both mineralized quartz and slate. A sample which apparently came from at least 8 or 10 feet below the surface is of slate, undoubtedly from near the contact with a quartz vein, and contains chalcopyrite and malachite in moderate amounts. Another specimen is of gray to dark reddish brown quartz, containing finely disseminated free copper, and, in the cracks, thin layers of malachite and azurite; a black coating, probably a hydrous manganese dioxide like psilomelane or wad, also occurs prominently in this rock. A third specimen of grayish to reddish drab quartz contains considerable amounts of free copper with which is associated some red cuprite. These last two specimens are said to be typical surface specimens. All of these are from the Three Friends claim, at Camp Black and White, which, according to Mr. Stanard, shows a mineralized zone 650 feet long with an average width of 12 feet. He also states that ore of this same class occurs on adjacent claims.

Impure gray chert carrying small amounts of chalcopyrite and malachite, and coated with considerable quantities of manganese oxide, occur with a decomposed mineralized igneous rock at the Black Trail claim, about 2 miles west of Mt. Skokomish.

The relation existing between the mineral-bearing and country rocks in the Sawtooth Range is typically illustrated by the section at Smith's camp, which is as follows:

Geologic section at Smith's Camp, from east to west.

	Feet
Diabase	20+
Quartz vein	8
Diabase	50
Quartz vein	20
Semi-metamorphosed black schist, mineralized near contact with vein	10
Alternating vertical beds of hard sandstone and shale or slate	70
Quartz vein	4
Sandstone and shale	20+

One wall of nearly all the veins in the district is igneous rock while the other may be schist, chert, calcareous chert or also igneous rock.

From the character of the specimens examined, it seems probable that the ores in this region consist largely of mineralized contact vein quartz with which is associated some of the country rock that has been locally mineralized along contacts with veins or contacts with intrusive diabase or other basic rocks. The most valuable ore in those veins which are associated with the iron-bearing cherts is usually immediately adjacent to the igneous wall. Next to the igneous wall in some of the veins is a zone from 4 to 12 inches or more in thickness, filled with decomposed iron ore; this zone extends for several feet below the surface and represents a zone of sulphides farther down.

According to Mr. Stanard, the belt of igneous and associated copper-bearing rocks extends at least as far as Mt. Constance in Secs. 6 and 7, T. 26 N., R. 3 W., 15 miles northeast of Mt. Skokomish.

Art. III.—*On the Analysis of the Mineral Neptunite from San Benito County, California*; by W. M. Bradley.

The rare mineral neptunite was discovered early in 1907 near the head waters of the San Benito River in San Benito County, California. It was associated in its occurrence with the new mineral benitoite, a barium titano-silicate, and at first was thought to be a new species and received the provisional name of carlosite.*

A crystallographic and optical study of these neptunite crystals has recently been published by Prof. W. E. Ford,† and the present chemical investigation is supplementary to that article. The mineral has previously been found only in the Julianehaab district, Greenland, and two analyses of the mineral were made from material obtained from this locality; one by Flink‡, and the other by Sjöström.§ The results of their analyses follow:

	SiO_2	TiO_2	FeO	MnO	CaO	K_2O	Na_2O	MgO	
Flink	51·53	18·13	10·91	4·97	—	4·88	9·26	0·49	=100·17
Sjöström	51·93	17·45	10·23	5·32	0·71	5·71	9·63	—	=100·98

The material used for the present analysis was obtained from the Brush Collection and was of ideal purity, it being selected from crystals similar to those used for crystallographic measurements.

Method of Analysis.—A very brief outline of the analytical methods employed may here be given. The mineral was fused with sodium carbonate and silica determined in the usual way. The filtrate obtained after the removal of the silica was used for a basic acetate precipitation, and the precipitate thus obtained eventually fused with acid potassium sulphate. The titanium was precipitated in a rather strongly acidified acetic acid solution in the presence of sodium acetate and SO_2 water by boiling the solution from three to five minutes. In the filtrate from the basic acetate precipitation the manganese was precipitated as MnO_2 by bromine water in the presence of sodium acetate, and after dissolving in strong SO_2 water was reprecipitated as ammonium-manganese phosphate. Calcium and magnesium were determined by the common gravimetric methods, and the alkalies by making a Smith's fusion. Ferrous iron was determined by dissolving the mineral

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* Univ. Calif. Pub., v, 9, pp. 149-153, 1907.

† This Journal, (4), xxvii, 235, 1909.

‡ G. För. Förh., xv, 196, 467, 1893; Zeitschr. Kr., xxiii, 346, 1894.

§ G. För. Fôrh., xv, 393, 1893.

in a mixture of hydrofluoric and sulphuric acids and finally titrating with $KMnO_4$.

The analyses agree essentially with those obtained by the previous investigators on the Greenland material with the exception that the percent of MnO present is much smaller while the amounts of lime and magnesia show a corresponding increase. The mineral is therefore a silico-titanate of iron and the alkalies. The results of the analyses are as follows:

	I	II	Average	Ratio		
SiO_2	52·91	52·83	52·87	·875		4·013
TiO_2	17·77	17·89	17·83	·222		1·017
MnO	·82	·88	·85	·011	·235	1·077
CaO	1·59	1·53	1·56	·027		
MgO	1·41	1·48	1·44	·035		
FeO	11·54	11·83	11·69	·162		
K_2O	5·11	5·06	5·08	·054	·208	·954
Na_2O	9·83	9·28	9·56	·154		
	100·98	100·78	100·88			

The ratios derived from the analysis yield very closely the following formula—$4SiO_2.1TiO_2.1\overset{II}{R}O.1\overset{I}{R}_2O$, which can be expressed by the general formula $\overset{I}{R}_2\overset{II}{R}TiSi_4O_{12}$ or (Na,K) (Fe, Ca Mg,Mn) Ti Si_4 O_{12}.

This is the same as that given by Flink* as a formula for the Greenland material.

In conclusion the author here makes known his indebtedness to Prof. W. E. Ford, who so kindly furnished the material for this investigation.

Mineralogical Laboratory of the Sheffield Scientific School of Yale University, New Haven, Conn., April 3, 1909.

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* Loc. cit.

Art. IV.—*Turtles from the Upper Harrison Beds;* by F. B. Loomis.

In spite of the considerable activity in collecting in the Harrison Beds in the vicinity of Agate, Nebraska, but three turtles have been described, and these are all from the upper beds. Two, *Testudo edae* and *T. hollandi*, are known from nearly complete shells, while *T. arenivaga* is based on simply the pygal and eleventh peripheral plate. During the explorations of the Amherst party in the country between the Muddy Creek and Agate, Neb., it was their good fortune to find in the Upper Harrison beds, among other turtle remains, most of the skeleton of *T. arenivaga* and two new Testudinæ, one of which is accompanied by an almost complete skeleton.

The entire lack of remains of aquatic forms has always struck the writer as very suggestive that these beds were deposited largely, at least, by winds; and of all the groups of land animals which are most likely to offer aquatic representatives the turtles are most favorable; but, while five species are now known, and their remains are by no means rare, every representative is an upland form, and so far all belonging to the genus Testudo. Among the mammals also the remains are all terrestrial forms. Then from the structure of the deposits, the irregular character of the bedding, the presence of occasional large pebbles, and the intermingling of very fine material with coarser sand, all point in the same direction, namely wind deposition.

The following paragraphs are descriptive of three turtles; of which *T. arenivaga* belongs with the large land tortoises characteristic of the Miocene of western America, while *T. brevisterna* and *T. undabuna* are quite aberrant from the typical forms of the epoch. The latter two were found on Muddy Creek in beds which also contained *Merychyus minimus* Peterson in abundance, and are, therefore, assigned by the writer to the Upper Harrison horizon.

Testudo arenivaga Hay.

Testudo arenivaga Hay, Ann. Carnegie Mus., IV, 1906, p. 16.

Testudo arenivaga Hay, Fossil Turtles of N. Amer., Carnegie Institute, 1908, p. 430.

The type of this large species is No. 1509 in the Carnegie Museum, and consists of the pygal and right eleventh peripheral plate, found in the Upper Harrison beds, "two miles north of Agate Spring Quarry." Within a mile or two of the above the Amherst party found a second specimen (No. 2165 of the Amherst Collection) which includes the portion found by the Carnegie party, together with the front of the plastron, the skull, shoulder girdle, humerus, pelvis, femur, a large number of dermal ossicles and fragments of other bones.

Three species of giant land tortoises have been described, all agreeing in a general way and being distinguished by having a dermal armature of small bones, in addition to the shell. These are *Testudo osborniana* from the Pawnee Creek beds, *T. impensa* from the Loup Fork of Montana, and *T. orthopygia* from the Upper Miocene of Kansas. To this group *T. arenivaga* belongs, making four representatives from the middle West.

The skull of *T. arenivaga* is relatively the widest of any of the known forms in this group (and all of the four are known by practically the whole skeleton), triangular in form, with rather heavy bones, and with the lateral angles extending slightly behind the occipital condyle. It is also relatively low.

Fig. 1.

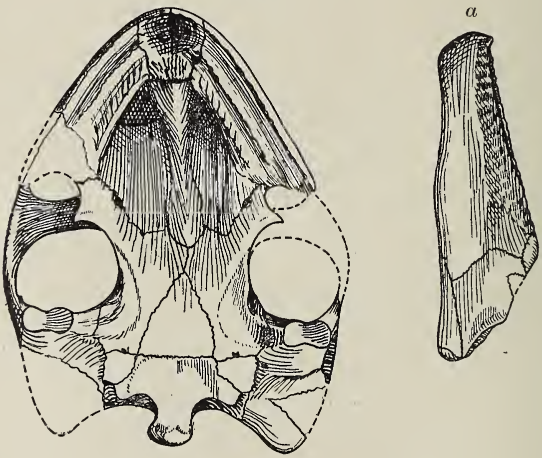

Fig. 1. *Testudo arenivaga,* the skull from the palatal aspect. ½ nat. size.
Fig. 1*a*. Lower jaw from the side. ½ nat. size.

Measurements.

Length, snout to occipital condyle	114^{mm}
Width across the quadrates	84^{mm}
Height at back of maxilla	37^{mm}

The top of the frontal is somewhat crushed, but the margins remain and show the interorbital region to be moderately wide

(32mm). The jugal arch is unusually heavy, being 19mm wide at the narrowest part. The palate is high vaulted and rather narrow. The masticatory surfaces of the maxillæ are wide, and have three ridges, and two longitudinal grooves. The marginal ridge is high and sharp, slightly dentate and overlaps the mandible extensively. The median ridge is low but acute, while the innermost one is rounded and crossed by shallow striæ. The two inner ridges do not continue onto the premaxillæ, which have a deep depression, into which evidently fitted a strong horny tooth on the lower jaw. The posterior nares open far enough back so that they are behind the shelf just described. On either pterygoid there is a slightly hooked ectopterygoid process.

Fig. 2.

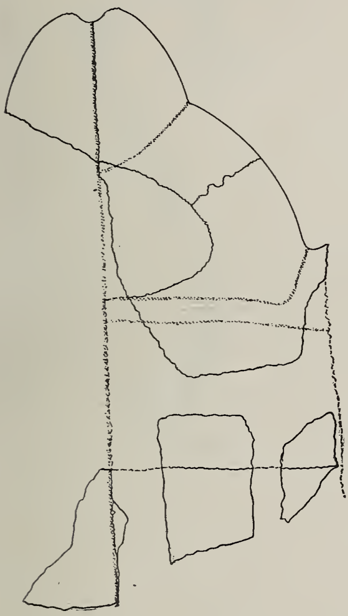

Fig. 2. The anterior portion of the plastron of *T. arenivaga*. ¼ nat. size.

The lower jaws are rather narrow, 26mm high at the coronoid, and the upper margin contains a deep groove, bounded by two sharp edges, of which the inner is the higher.

Of the carapace but a small portion of the rear was preserved, but that fortunately included the half of the pygal, suprapygal and the eleventh peripheral, which correspond almost exactly in dimensions and thickness with those of the type, so that the association may be considered unquestionable, inasmuch as the two came from within a mile or two of each other.

Of the plastron the anterior lobe of the left side and some fragments were found. The whole lobe is about 330mm wide and 240mm long, indicating that the shell was relatively long and narrow. The lip is prominent, being 148mm wide at the base and 75mm long on the median line. The anterior corners are rounded and there is a small notch in front, making a form in itself distinctive. From the front, the lip thickens rapidly until, when 115mm back, it is 75mm thick. It then drops down abruptly, the escarpment being strongly excavated behind. The following measurements of plastral scutes are all that can be given: On the median line, the gulars occupy 125mm, humerals 105mm, and the pectorals but 15mm.

The shoulder girdle is practically complete. The scapula is a flattened bone about 145^{mm} long and, near the glenoid end, is about twice as broad as it is thick. It makes an angle of 120° with the procoracoid process, which is 95^{mm} long. The coracoid is a broad triangular bone, measuring 85^{mm} along the medial side, 75^{mm} along its front border and 105^{mm} along the posterior border. The humerus is a heavy bone, 173^{mm} long, with a head 45^{mm} in diameter. However, for the size of the skull, this, as is also the case with the other limb bones, is relatively light when compared with that of *T. orthopygia*, *T. osborniana*, or *T. pensa*. The lesser tubercle is swung well to the rear; so the intertubercular sulcus between it and the wing-like greater tubercle is unusually narrow and deep.

Fig. 3.

Fig. 4.

Fig. 3. Humerus of *T. arenivaga* from the radial size. ½ nat. size.
Fig. 4. Femur of *T. arenivaga*. ½ nat. side.

The pelvis is also relatively light and offers no particular features. The femur is relatively small, being 142^{mm} long, the shaft being much flattened toward the distal end. At the condyles it is 56^{mm} wide. A few phalanges are present, the end ones being about 25^{mm} long; and the next to the last only about 15^{mm}.

On the under sides of the feet and along the forelimb up to the elbow, and presumably under the tail, numerous denticles occur. Along one fore limb over 50 were found. As Hay has suggested, these helped to close the openings at the front and rear of the shell. They are characteristic of these large forms; and, judging from the fact that in every species the skeleton has been preserved, they may well have been most effective in completing the armature. They may be used to bind together into a subordinate group such Testudinæ as possess them.

Testudo brevisterna sp. nov.

The type of this species is No. 2006 in the Amherst Collection and was found in the Upper Harrison beds, on Muddy Creek in the north edge of Laramie Co., Wyoming. The type includes the carapace, plastron, skull, shoulder girdle, fore limb (except foot), pelvis and the hind limb (except foot). The skeletal portions were found within the shell and indicate that the turtle died while withdrawn. It apparently lay some time before being buried, as the bones are in many cases eaten into, either by animals or decay. This specimen was found in close proximity to the skeleton of *Merychyus minimus*, which marks the beds on Muddy Creek as Upper Harrison.

The turtles nearest in the arrangement of their plates to *Testudo brevisterna* are *T. vaga* from the Pawnee Creek beds and *T. edae* from the Upper Harrison, both of these agreeing in having only neurals 1 and 3 tetragonal, while the second is octagonal: but in *T. brevisterna* the fourth neural is hexagonal, while in both the other forms it is octagonal. *T. edae* is further isolated by having only seven neurals. The species *T. brevisterna* is peculiar in the abrupt way the carapace falls off behind, the rear portion of the shell being almost vertical, and its middle portion extending below the plastron, thus practically closing the rear of the shell.

The skull of this specimen is nearly complete, only the left quadrate region and the basioccipital being lost. In this skull there are such marked peculiarities that, among the few Testudinæ of this type, the writer finds no other species with which to compare it. The skull is wide and short, being as wide across the quadrate region as it is long from the snout to the occipital condyle. It is very low and the arcades are heavy. The large prefrontals (18^{mm} along the median line) almost exclude the frontals from bordering on the orbit. The small frontals (12^{mm} long) are much reduced, the larger parietals overshadowing them. The vault of the palate is very low and has a median ridge running from the basisphenoid onto the premaxillæ. The masticatory surface has three ridges and two longitudinal furrows. The low, sharp outer ridge bounds the jaw, overlapping the lower jaw but little. The middle and inner ridges are still lower and rather obtuse. The median ridge mentioned above as continuing onto the premaxillæ separates two deep pits, one on either side, which evidently received two horny teeth on the front of the lower jaw. There is a strong ectopterygoid process on either pterygoid bone. The opening for the ear is greatly narrowed, making a very characteristic feature. (See fig. 5*a*.)

Fig. 5.

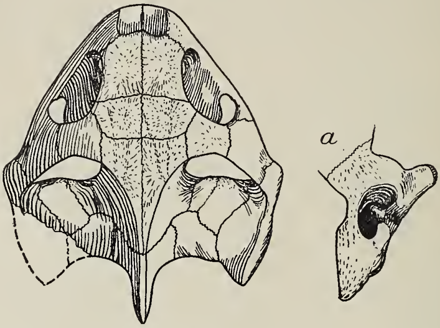

Fig. 5. Skull of *T. brevisterna* from above. ½ nat. size.
Fig. 5*a*. The quadrate and otic region seen from the side to show the narrow ear opening and the forward projection of the quadrate. ½ nat. size.

Measurements.

Length from the snout to the supra occipital crest	89$^{\mathrm{mm}}$
Length from the snout to the occipital condyle (estimate)	70$^{\mathrm{mm}}$
Width across the quadrates	70$^{\mathrm{mm}}$
Width of interorbital region	25$^{\mathrm{mm}}$
Length of ear opening	14$^{\mathrm{mm}}$
Height of ear opening	6$^{\mathrm{mm}}$

The short, widespread lower jaws have a longitudinal groove bounded by sharp ridges of nearly equal height. The jaw is 55$^{\mathrm{mm}}$ long and 19$^{\mathrm{mm}}$ high at the coronoid.

The carapace is only 386$^{\mathrm{mm}}$ long and nearly as wide (360$^{\mathrm{mm}}$), being high arched (148$^{\mathrm{mm}}$ high). The greatest width is near the front and it narrows slightly as it approaches the rear. The back of the shell drops off very abruptly, being almost vertical, and extending below the plastron near the middle line. The dimensions of the various plates appear in the table below:

	Neurals	
	Length	Width
1	63	40
2	40	46
3	38	42
4	36	52
5	34	48
6	29	45
7	28	45
8	38	36

	Vertebrals	
	Length	Width
1	115	125
2	85	98
3	90	100
4	68	80
5	104	155

Fig. 6.

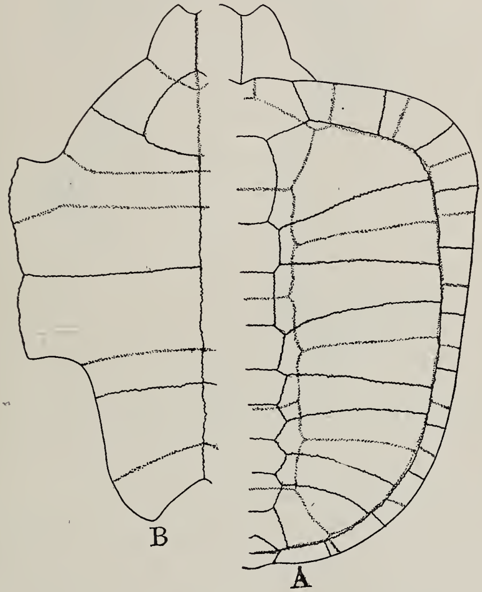

Fig. 6*a*. The carapace of *T. brevisterna*, projected on a flat surface. The posterior part is a little spread. ¼ nat. size.
Fig. 6*b*. Plastron of same.

This individual seems to be very old and the sulci marking the outline of the scutes are but dimly marked. There is a low boss on the first neural. Both neural 1 and 3 are tetragonal, 3 is octagonal and the others are hexagonal. The upper suprapygal is as usual in the genus. Costals 2, 4, 6, and 8 are narrow above, but spread distally, having a wide base below. Costals 1, 3, 5, and 7, on the other hand, are wide above and narrow below.

The plastron is 429^{mm} long and 220^{mm} wide, the anterior lip projecting far in front of the carapace. The front of the plastron is turned upward, the lip projecting straightforward from it. The rounded anterior end of the lip is deeply notched, and from the front it thickens until about 70^{mm} back the lip is about 30^{mm} thick. Just behind this point it drops down, making a considerable wall. The endoplastron is 70^{mm} long and 86^{mm} wide. The relationships of the different elements are shown in the scale drawing, fig. 6.

Fig. 7.

Fig. 8.

Fig. 7. Humerus of *T. brevisterna* from the radial side. ½ nat. size.
Fig. 8. Femur of *T. brevisterna*. ½ nat. size.

The scapula is a flattened bone (92^{mm} long) making an angle of 119° with the procoracoid (62^{mm} long). The humerus is greatly flattened and very broad, the lesser and greater tubercules being wide spread, and having a broad intertubercular sulcus between them. The head of the humerus, however, is relatively small (see fig. 7), but the distal end of the bone is again wide and flat.

The pelvis has a short stout ilium, and the whole build of pubis and ischium is heavy, especially the short prepubic process. The femur, unlike the humerus, is a short, stout bone, 82^{mm} long and widely oval in section. Both the tibia (65^{mm} long) and the fibula (70^{mm} long) are rod-like with a circular cross section, and taper gradually toward the distal end. The feet are wanting.

While the cervical and caudal vertebræ are present they offer no specific characters, unless it is that the tail was short and weak.

Testudo undabuna sp. nov.

The type of this species (No. 2007 in the Amherst collection) is a carapace, lacking the pygal and eleventh peripherals, and the median portion of the plastron, the shell belonging to a very primitive type of Testudo. It was found in the Upper Harrison beds on Muddy Creek, Laramie County, Wyoming.

The species is peculiar in having the suture between the first and second costal plates start from the first neural plate, making it hexagonal, a condition paralleled among American fossil turtles only in *Testudo laticuneata* from the Oligocene. No neural plates are octagonal and only the third is tetragonal. The surface of the carapace is covered by undulatory lines which follow the outlines of the epidermal scutes.

Fig. 9.

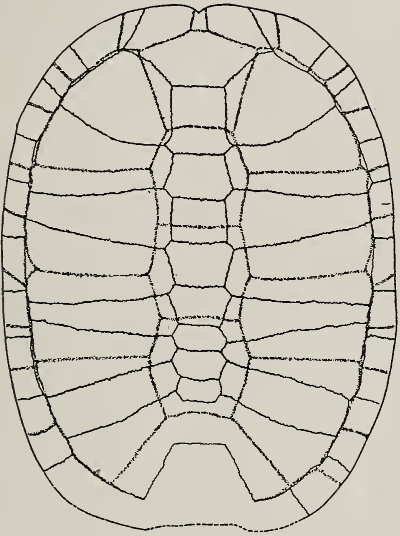

Fig. 9. Carapace of *Testudo undabuna* as projected on a flat surface. ½ nat. size.

The carapace of the type is 205^{mm} long and 155^{mm} wide, the outline of the shell being regularly ovate with a slight notch in front, and unusually low vaulted for a land tortoise. The dimensions of the neurals are given in the table below.

	Neurals	
	Length	Width
1	30	22
2	17	30
3	20	22
4	17	20
5	18	28
6	12	28
7	12	24
8	9	18

	Vertebrals	
	Length	Width
1	46	57
2	37	47
3	36	52
4	46	52
5	50	82

The second, fourth, sixth and eighth costals are narrow above and wider below; the first, third, fifth, and seventh are wide above and narrow below.

As only the central portion of the plastron is preserved, but few characters can be gleaned from it. The species seems to be at least fairly common, both in the beds along the Muddy Creek and also along Raw Hide Creek, no less than five specimens having been found.

Amherst, Mass.

Art. V.—*Pyrogenetic Epidote*;[*] by B. S. Butler.

An occurrence of epidote as an apparently original constituent of a dike rock was observed by the writer in 1907, while engaged in field work in the Shasta County copper region, California. This recalled the question as to whether or not epidote is ever a pyrogenetic mineral. In the occurrence to be described, the evidence of primary origin seems unusually good, and, although the material obtained is not as fresh as could be desired, since all the specimens were collected from surface outcrops, yet it is thought worthy of presentation.

In order that the evidence may be properly weighed, it may be well to preface it with a brief review of some of the occurrences described by previous observers.

One of the best known of these in the United States is that of allanite and epidote in the granites of Ilchester, Maryland, described by Professor W. H. Hobbs.[†] Concerning the origin of the minerals Professor Hobbs says: "With little doubt the latter (allanite) is one of the earliest separations from the magma. The origin of the epidote is not so easily settled, but the 'stretched' character of the granite is in favor of a metamorphic origin, through pressure. Against such a view is the discovery by Professor Williams that the Woodstock granite, which is particularly rich in these intergrowths, shows no evidence of cataclastic action."[‡] In a later publication the author expresses the belief that the epidote of the Ilchester granites, in some cases at least, is an original mineral. The Maryland granites were later studied by Mr. C. R. Keyes,[§] who concludes that both the allanite and epidote are of primary origin. A. Lacroix[‖] describes intergrowths of epidote and allanite closely resembling those of Ilchester, in which the epidote is considered as an original mineral. Professor W. C. Brögger[¶] describes similar intergrowths and considers the epidote, in some cases at least, to be of pseudomorphic origin. Professor Frank D. Adams[**] describes the occurrence of epidote and allanite in granites from Wrangell Island, Alaska, and Pelly River, Yukon district, Alaska. In both cases the epidote is considered as a mineral which has grown in the rock after its consolidation, but without recrystallization of the other constituents.

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[*] Published by permission of the Director of the U. S. Geological Survey.

[†] This Journal (3), vol. xxxviii, pp. 223–228.

[‡] Am. Geol., vol. xii, p. 218, 1893.

[§] Geol. Soc. Am. Bull., vol. iv. pp. 305–312.

[‖] Bull. de la Soc. Française de Minéralogie, vol. xii, Apr. 1889.

[¶] Zeitschrift für Krystallographie, xvi, p. 99, 1890.

[**] Canadian Record of Science, 1891, p. 344.

Mr. W. H. Turner* considers epidote occurring in a fresh soda-granite from California as probably original. Messrs. Alfred E. Barlow and W. F. Ferrier,† describing epidote occurring in Laurentian gneisses, consider it as primary, and in a classification of the rocks, the micaceous gneisses are subdivided on the basis of primary and secondary epidote. These are described by the authors as follows:

"Biotite-epidote-gneiss. The combination of biotite and epidote as the principal colored constituents forms a well-defined rock-type which has been found to be remarkably constant over large and widely separated areas . . . . . The rocks are undoubtedly of irruptive origin, and are, in fact, foliated granitites, thoroughly holocrystalline and granitoid, varying from coarsely to finely crystalline."

Under the description of the epidote they make the following statements:

"Next to the biotite, this is by far the most abundant of the coloured constituents of the granitic gneisses and it also enters largely into the composition of the more basic hornblendic ones. In addition to the ordinary occurrence of the epidote as an alteration product, we have also the strongest evidence that it exists in a large number of cases as an original and important constituent of the rock mass.

The manner in which the perfectly fresh crystals, possessing sharply defined outlines, occur inclosed by wholly unaltered biotite in rocks which have been subjected to only a slight degree of pressure, admits of no reasonable doubt as to their primary nature . . . . . The crystals occasionally contain cores of a pleochroic brownish substance which is probably allanite, but no thoroughly typical examples of that mineral were detected."

As seen from the foregoing descriptions, in most of the occurrences where epidote has been considered primary it has been associated with allanite, the two exceptions being the occurrence noted by Mr. Turner, where allanite is not mentioned as a constituent of the soda-granite, and that of Messrs. Barlow and Ferrier, in which allanite is only rarely associated with the epidote.

The evidence of pyrogenetic origin adduced in these cases has apparently not been entirely convincing. Several of the recent text-books on petrography question the occurrence of epidote as an original constituent of igneous rocks. Mr. Waldemar Lindgren,‡ in a recent paper: "Relation of ore deposits to physical conditions," does not include epidote

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* Jour. Geol., vol. vii, p. 155.

† Canadian Geol. Survey, vol. x, pp. 70–87, 1907.

‡ Econ. Geol., vol. ii, p. 105, 1907.

among the pyrogenetic minerals, and Mr. William H. Emmons,* in a later article: "A genetic classification of minerals," questions its occurrence as an original constituent of igneous rocks.

The epidote in Shasta County, California, occurs as an accessory mineral in small dikes cutting an extensive mass of soda-granite porphyry. This main intrusive is the enclosing rock of the copper deposits west of the Sacramento River. It is roughly elliptical in outline with major diameter exceeding 10 miles and the minor diameter 3 to 4 miles. Near the center of this intrusive mass, in the vicinity of the Balaklava, Shasta King, and Spread Eagle mines, are several small dikes which appear, from field relation and chemical composition, to be the result of differentiation from the main intrusive rock. It is in these dikes that epidote is found with the characteristics of an original mineral.

Both the large intrusive mass and the dikes are of unusual composition, being characterized by very low content of potassium and calcium with high soda.

Analyses of the soda-granite porphyry and one of the dikes by Mr. George Stieger, of the U. S. Geological Survey, give the following composition:

	I	II
SiO_2	80·09	68·75
Al_2O_3	10·80	16·75
Fe_2O_3	1·07	·48
FeO	·83	1·72
MgO	·58	·83
CaO	·38	·89
Na_2O	5·60	6·95
K_2O	none	·80
H_2O-	·24	·84
H_2O+	·52	1·52
TiO_2	·16	·27
ZrO_2	·01	none
CO_2	none	none
P_2O_5	·04	·16
SO_3	none	none
S	none	none
MnO	·02	·04
BaO	none	·03
SrO	none	·03
	100·34	100·06

I. Soda-granite porphyry near Shasta King mine.
II. Porphyry dike near mouth of north tunnel of Spread Eagle mine.

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* Econ. Geol., vol. iii, p. 611, 1908.

These dikes, which occur scattered over several square miles in this locality, differ somewhat in appearance, chiefly due to difference in weathering, but are very uniform in mineral composition. The freshest specimen obtained was from the dike at the Spread Eagle tunnel. This is a greenish-gray porphyritic rock containing phenocrysts of quartz, plagioclase, altered biotite and epidote. The quartz crystals are not abundant and show marked corrosion. The plagioclase phenocrysts are very striking, being almost pure white in color and nearly euhedral in form, the larger reaching 8^{mm} in length. Biotite crystals are rather scattering and show strong chloritization. The epidote occurs in well-formed crystals scattered sparingly through the rock. The largest observed was 12^{mm} in length, though most of the crystals do not exceed 5^{mm} in greatest dimension. They are of sufficient size and abundance to attract the attention at once and were found in every dike of this character examined.

Under the microscope the quartz phenocrysts show pronounced corrosion, having entirely lost their crystal outline. The feldspar crystals in many cases are twinned according to both the albite and pericline laws. Extinction on 010 varies from +7 to +10, with index slightly lower than Canada balsam. These properties correspond to an oligoclase with a composition about Ab_5An_1. The crystals are clouded with minute dark specks and in some instances there has been considerable kaolinization. The biotite has suffered extreme alteration, in some cases to a green pleochroic mica with the separation of iron ore; in other cases alteration has produced chlorite, epidote and iron ore. In a few instances serpentine has resulted from the alteration. A few crystals of unaltered muscovite or paragonite are present in the specimens.

The groundmass is composed of unstriated feldspar, with small amounts showing twinning, also of quartz and altered mica. The analyses indicate that the feldspar of the groundmass is lower in lime than the phenocrysts. Accessory minerals are epidote, apatite, zircon, and titanite. Many of the epidote individuals evidently once possessed a definite crystal outline, though in most cases there has been enough corrosion by magma to destroy the sharp crystal faces. In some instances this corrosion has produced embayments in the crystals. The contact between the epidote and the groundmass is perfectly definite, there being no fingering out of the epidote into the enclosing groundmass. A few crystals of quartz and apatite are included in the epidote. The included quartz crystals show nearly perfect crystal outline, and have escaped the corrosive action of the magma, which has affected the epidote and the quartz not thus protected. The evidence indicates that the quartz and epidote were among the earliest minerals to crystallize; both were earlier than the feldspar and biotite, at any rate the latter minerals do not show the corrosive effects that characterize the former.

The epidote possesses the optical properties characteristic of that mineral. Pleochroism $\mathfrak{a}$ pale greenish-yellow, $\mathfrak{b}$ pale lemon-yellow, $\mathfrak{c}$ nearly colorless. Absorption $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. Twinning plane 100. Cleavage 001 and 100 distinct. Plane of optic axes 010. $\mathfrak{a} \wedge c = 2^\circ\ 25'$ average of several readings. Angle between 100 and 001 = $114^\circ\ 26'$ average of measurement on several crystals. Optical character (−). $\gamma - \alpha = {\cdot}024$, determined by table of birefringences.

A separation of the epidote was made by breaking the crystals from the matrix. In this manner material that was fully 50 per cent epidote was obtained. This was crushed to pass a 100-mesh sieve and the powder separated by Thoulet's solution at maximum density. The material obtained was examined microscopically and found to be practically pure epidote. An analysis of this material by Mr. W. T. Schaller, of the U. S. Geological Survey, gave the following composition:

Analysis of Epidote from Shasta Co., Cal.

SiO_2	38·22
TiO_2	0·33
Al_2O_3	25·12
Fe_2O_3	8·75
FeO	1·25
MnO	0·19
MgO	trace
CaO	22·77
K_2O	·06
Na_2O	·11
H_2O-	·52
H_2O+	3·04
	100·36
Rare earths	none
Density (approximately)	3·29

It is seen that, disregarding the minor constituents, the mineral conforms very closely to the formula $(Ca,Fe)_2\,(AlOH)\,(Al, Fe)_2\,(SiO_4)_3$, the molecular ratio of calcium to ferrous iron being $CaO : FeO :: 24 : 1$, and that of aluminium to ferric iron $Al_2O_3 : Fe_2O_3 :: 4{\cdot}5 : 1$.

Aside from the foregoing evidence of the primary origin of the epidote there are additional reasons for believing that it is not secondary. The large crystals of epidote appear with equal abundance in various stages of alteration of the different dikes. Where secondary epidote develops in the alteration of biotite and feldspar, it is in minute grains and shows no tendency to collect in large crystals. The very low lime content of the rock would permit of the formation of but a small amount of epidote, and it is difficult to conceive of conditions of alteration that would cause all this to collect in a few large crystals, if it had been originally disseminated through the rock. In the freshest dikes the feldspars show but slight alteration, and could not have furnished sufficient CaO from this alteration to form the epidote. The enclosing rock is extremely low in lime, and cannot be looked upon as a source of this material for the formation of the epidote. The dikes are near the center of a large intrusive mass and therefore are probably not affected by formations surrounding this large mass.

Considering the dikes as the result of differentiation of the magma represented by the main intrusive mass, it is seen that there has been a decrease in SiO_2 with increase in most of the remaining oxides; the relative increase in lime is much greater than in soda. From this it would naturally be expected that the feldspar of the dikes would be distinctly more basic than that of the main intrusive. The feldspar of the groundmass in both rocks is too small for accurate determination, but so far as can be judged by the phenocrysts, there is little difference in the composition of the feldspars in the main intrusive and in the dikes. Assuming that the feldspars in the two rocks are of the same composition, the excess of lime in the dike rock may be considered as available for the formation of epidote.

In calculating the composition of the dike rock we may assign enough CaO to combine with available P_2O_5 to form apatite, an amount equal to the total CaO present in the main intrusive to form anorthite, and there is still remaining sufficient to form 1·41 per cent of epidote of the composition shown by the analysis. As the amount of feldspar in the dikes is greater than that in the enclosing rock, it would require slightly more CaO than is present in the main intrusive to form feldspar of the same composition. This would reduce the amount of epidote slightly, but it would probably still be above one per cent. It is difficult to estimate the percentage of epidote present in the scattered crystals, but it certainly seems to correspond well with the amount roughly calculated above.

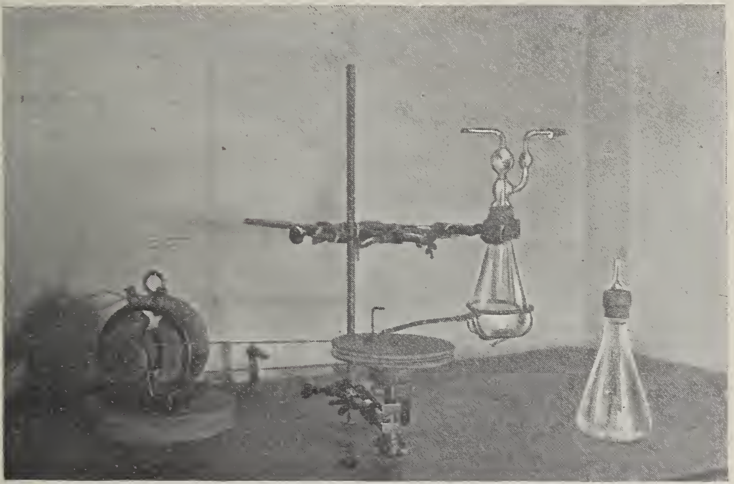
Washington, D. C.

ART. VI.—*The Gravimetric Determination of Free Iodine by the Action of Metallic Silver;* by F. A. GOOCH and CLAUDE C. PERKINS.

[Contributions from the Kent Chemical Laboratory of Yale University—cc.]

WHEN in analytical operations it becomes desirable to determine free iodine in the presence of iodine combined in an iodide, it is usual to have recourse to volumetric procedure involving the preparation of standard sodium thiosulphate, for use in neutral or acid solution, or of standard arsenite, for use in solutions made alkaline by a bicarbonate.

FIG. 1.



The present paper is an account of an endeavor to utilize the well-known affinity between silver and iodine as the basis of a gravimetric method for the determination of iodine in general, and, incidentally, for the gravimetric standardization of iodine solutions to be used in volumetric analysis.

Inasmuch as the facility with which combinations may take place between substances varies with their physical conditions, several preparations of silver were tried with a view to finding the form of silver best adapted to the purpose of taking up iodine in analysis. The iodine was used in N/10 solution prepared in the usual way (12·7 gms. of iodine to 18 gms. of potassium iodide in one liter) and standardized against arsenious acid.

The procedure was simple. The standard N/10 iodine solution was drawn from a burette into a 250$^{cm^3}$ Erlenmeyer flask containing a weighed amount of finely divided silver. The flask, properly trapped and attached to a mechanical shaker adjusted to give the liquid a rapid rotary motion, was shaken until the iodine color had vanished. The liquid, usually 50$^{cm^3}$ in volume, was diluted to about 100$^{cm^3}$ and the residue of silver and silver iodide, collected in a perforated crucible fitted with asbestos felt, was washed, dried at 130° to 140°, and weighed. The difference between the weight of silver taken and that of the residue of silver and silver iodide should, according to the theory of action, be the measure of the free iodine. The accompanying cut shows the mechanical shaker and the adjustment of apparatus used throughout the work. The flask at one side, fitted with a bulb-trap held in place by an outer rubber band, was used in the experiments of Tables I and II. The flask mounted upon the shaker was used for the operations carried out in hydrogen and recorded in Tables III and IV.

In Table I are given the results of experiments made with silver reduced in the wet way, by the action of zinc upon silver chloride (A), silver nitrate (B), or silver iodide (C); and, in a dry way, by the action of hydrogen upon silver sulphide (D), or upon silver oxide (E). In the first set of experiments of each sort the reduced silver was dried and used without special previous treatment; in the second set of each sort the reduced silver was shaken with a solution of potassium iodide, washed, and dried before being used to absorb the iodine. The object of shaking the reduced silver with potassium iodide was to convert to silver iodide any incompletely reduced silver chloride, nitrate, or sulphide, and this treatment does reduce considerably the very large error noted in all of the experiments with the untreated silver; but the similar, if less marked, effect upon silver reduced from the iodide suggested that a part of the unfavorable effects in the case of the untreated silver might be due to action between potassium iodide and metallic components of the zinc. Even in those experiments in which the reduced silver was previously treated with potassium iodide the errors are too large and too variable for a good analytical process.

TABLE I.

The Action of Silver Reduced by Chemical Processes.

Silver taken grm.	Iodine taken grm.	Increase in weight of silver grm.	Error in iodine grm.	Remarks
(A) The action of silver reduced from AgCl by zinc.				
3	0·6473	0·6833	+0·0360	The silver was used without previous treatment
3	0·6473	0·6861	+0·0388	
3	0·6473	0·6877	+0·0404	
3	0·6473	0·6830	+0·0357	
3	0·6473	0·6829	+0·0356	
3	0·6461	0·6475	+0·0014	The silver was previously treated with KI
3	0·6461	0·6483	+0·0022	
3	0·6461	0·6494	+0·0033	
(B) The action of silver reduced from $AgNO_3$ by zinc.				
3	0·6461	0·6677	+0·0216	The silver was used without previous treatment
3	0·6461	0·6656	+0·0195	
3	0·6461	0·6464	+0·0003	The silver was previously treated with KI
3	0·6461	0·6472	+0·0011	
3	0·6461	0·6470	+0·0009	
(C) The action of silver reduced from AgI by zinc.				
3	0·6461	0·6513	+0·0052	The silver was used without previous treatment
3·27	0·6461	0·6519	+0·0058	
3	0·6461	0·6514	+0·0053	
3	0·3217	0·3257	+0·0040	
3	0·3217	0·3261	+0·0044	
3	0·6434	0·6444	+0·0010	The silver was previously treated with KI
3	0·3217	0·3231	+0·0014	
(D) The action of silver reduced from Ag_2S by hydrogen.				
3	0·6473	0·6574	+0·0101	Silver used without previous treatment
3	0·6473	0·6577	+0·0104	
3·002	0·6461	0·6473	+0·0012	The silver was previously treated with KI
3	0·6461	0·6472	+0·0011	
3	0·6461	0·6475	+0·0014	
3	0·6461	0·6483	+0·0022	
3	0·6461	0·6525	+0·0064*	
(E) The action of silver reduced from Ag_2O by hydrogen.				
3	0·3217	0·3250	+0·0033	Silver used without previous treatment

* Stood for several hours in the solution.

The experiments next described were made with silver deposited electrolytically from a solution of silver nitrate upon a platinum cathode, the anode being enclosed within a porous cell to prevent admixture of the silver dioxide formed at the anode with the metallic silver at the cathode. Experience showed that, while the bright and crystalline deposit which formed upon a stationary cathode lacked in absorptive power, the product obtained by continually oscillating the cathode during the deposition of the metal, broken and dark when formed, proved to be sensitive to iodine as well as pure. The results of experiments with electrolytic silver thus prepared are given in Table II.

Table II.

The Action of Electrolytic Silver.

Silver taken grm.		Iodine taken grm.	Increase in weight of silver grm.	Error in iodine grm.
2·8184		0·6461	0·6494	+0·0033
3·2130		0·6461	0·6490	+0·0029
2·0514		0·6461	0·6491	+0·0030
3·0102		0·6461	0·6490	+0·0029
7·5943	(cryst)	0·6479	0·6513	+0·0034

Though the silver used in this process was pure, the errors observed are positive and high; and this fact emphasizes an obvious inference from the previous work that the excess in weight is due to the absorption by the silver of an extra amount of iodine liberated from the potassium iodide by prolonged agitation in contact with the air. In harmony with this idea is the fact, observed throughout the entire series of experiments with silver reduced by chemical processes and subsequently treated with potassium iodide, that the error is greatest when the time used to accomplish the absorption is the longest. This was especially marked in the experiments with silver reduced by hydrogen, in which the largest amount of time was needed, on account of the less sensitive character of the glistening and filamentary metal.

Moreover, direct experiments in which the silver was shaken with 50$^{cm^3}$ of a solution of potassium iodide, 20^{grm} to the liter, fully confirmed the idea that the action of air must be prevented during the agitation of the solution of the iodide in contact with silver; for in these experiments it was found, that from the solution of potassium iodide shaken in contact with air finally divided electrolytic silver absorbed 0·0010^{grm} of iodine in fifteen minutes, that silver reduced by zinc from silver iodide absorbed 0·0012^{grm} of iodine in fifteen minutes, that silver reduced from the sulphide by hydrogen took up 0·0032^{grm}

of iodine in one hour, and that crystalline electrolytic silver took up 0·0051$^{\text{grm}}$ in one hour and forty-five minutes.

This action of air once shown, the next step was to investigate the behavior of silver in contact with potassium iodide protected from the action of the air. In Table III are recorded

TABLE III.

The Action of Silver upon N/10 Iodine in an Atmosphere of Hydrogen.

Silver taken grm.	Iodine taken grm.	Increase in weight of iodine grm.	Error in iodine grm.	Average error in iodine grm.
(A) The action of silver reduced from AgCl by zinc and treated with KI.				
3·0000	0·6461	0·6464	+0·0003	
1·0000	0·6447	0·6448	+0·0001	+0·0002
(B) The action of silver reduced from AgI by zinc and treated with KI.				
3·6293	0·3217	0·3221	+0·0004	
3·2049	0·3217	0·3225	+0·0008	
3·0000	0·3217	0·3219	+0·0002	
3·0068	0·3217	0·3212	−0·0005	
3·0049	0·3217	0·3221	+0·0004	
3·0026	0·6434	0·6441	+0·0007	
2·9990	0·3217	0·3214	−0·0003	
3·0005	0·3217	0·3214	−0·0003	+0·0002
(C) The action of silver reduced from Ag_2S by hydrogen and treated with KI.				
3·0000	0·6461	0·6463	+0·0002	
3·0000	0·6461	0·6460	−0·0001	+0·0001
(D) The action of silver reduced from Ag_2O by hydrogen.				
3·0000	0·6434	0·6443	+0·0009	
3·0000	0·6434	0·6430	−0·0004	+0·0003
(E) The action of silver reduced electrolytically from $AgNO_3$.				
4·4189	0·6447	0·6447	±0·0000	
3·0025	0·6447	0·6448	+0·0001	
3·0009	0·6447	0·6443	−0·0004	
3·0157	0·6447	0·6445	−0·0002	
3·0000	0·6447	0·6444	−0·0003	
3·0000	0·6447	0·6452	+0·0005	
3·0004	0·6447	0·6443	−0·0004	
3·0043	0·6447	0·6443	−0·0004	
3·0000	0·6434	0·6430	−0·0004	
3·5810	0·3217	0·3221	+0·0004	
3·0000	0·3217	0·3219	+0·0002	−0·0001

the details of experiments in which the standard N/10 solution of iodine in potassium iodide was shaken N/10 silver in flask filled with hydrogen and closed.

These results make it plain that free iodine may be determined with accuracy in the presence of potassium iodide by shaking the solution with metallic silver in a closed flask filled with hydrogen and determining the increase in weight of the silver. Silver reduced from a silver salt by zinc or from silver sulphide by hydrogen may serve the purpose, provided it is subjected to a preliminary treatment with potassium iodide, and silver reduced from the oxide by hydrogen is also serviceable; but the best form of silver, and the one most easily prepared in the pure state, is that deposited electrolytically upon a small oscillating cathode of platinum from a solution of silver nitrate, the platinum anode being enclosed in a porous cell. The shaking of the silver may be done by hand or by some simple form of mechanical shaker like that described in the figure. The time required for the absorption of approximately $0·65^{grm}$ of iodine in 50^{cm^3} of liquid was 15 to 25 minutes. The mean error of the eleven determinations in which electrolytic silver was employed proved to be $-0·0001^{grm}$ between extremes of $+0·0005$ and $-0·0004^{grm}$.

To test the accuracy of the process in alkaline solution experiments similar to those above were made, in which the

Table IV.

The Action of Silver upon N/10 Iodine in an Alkaline Solution.

Silver taken grm.	Iodine taken grm.	Increase in weight of silver grm.	Error in iodine grm.	Average error grm.
(A) The action of silver shaken in air with $NaHCO_3$.				
2·0110	0·3217	0·3221	+0·0004	
3·6684	0·3217	0·3219	+0·0002	
3·0056	0·3217	0·3235	+0·0018	
3·0093	0·3217	0·3245	+0·0028	
3·0058	0·3217	0·3224	+0·0007	
3·6686	0·3217	0·3243	+0·0026	
2·9993	0·3217	0·3261	+0·0044	
3·0013	0·3217	0·3235	+0·0018	
3·0014	0·6434	0·6485	+0·0051	+0·0022
(B) The action of silver shaken in an atmosphere of hydrogen with $NaHCO_3$.				
3·0014	0·3217	0·3216	−0·0001	
3·0169	0·3217	0·3216	−0·0001	
3·0083	0·6434	0·6433	−0·0001	
3·0016	0·2500	0·2503	+0·0003	
3·0069	0·3217	0·3219	+0·0002	+0·0001

mixture of silver and iodine was made alkaline by adding about 10^{cm^3} of a saturated solution of sodium bicarbonate. The results of the experiments in Table IV, which show irregularities when made in air and a very high degree of accuracy when the shaking was done under hydrogen, prove the absorption of iodine to be equally as exact in the alkaline as the neutral solution.

The process described, in which free iodine is absorbed by electrolytic silver under hydrogen, either in neutral solution or in a solution made alkaline with an acid carbonate, should be applicable in many analytical operations, as well as in the gravimetric standardization of the usual iodine solution of volumetric analysis.

ART. VII.—*Pyromorphite from British Columbia, Canada*;[*]
by O. BOWLES.

Introduction.—During the summer of 1907 Prof. W. A. Parks of the University of Toronto visited the Society Girl Mine in Southeastern British Columbia, situated a short distance east of the famous St. Eugene Mine in the Moyie District. Here he collected a large number of well-crystallized specimens of pyromorphite, which were brought to the Mineralogical Laboratory of the University of Toronto, where the writer was permitted to investigate them.

General description.—In this locality the pyromorphite is found in association with galena and cerussite in the fractured country rock. The cerussite and pyromorphite appear to be of secondary origin through the decomposition of galena in fracture cavities. A white clay surrounding the pyromorphite crystals suggests the probable action of percolating water, which may have supplied the phosphorus from organic matter at higher levels.

The mineral occurs in the form of densely crowded crystal aggregates. Most of the crystals are wax-yellow in color, while some are green; and these two varieties exhibit some interesting differences which are described later. The crystals are brittle, of a resinous luster, and in their property of light transmission vary from opacity or sub-translucency in the larger to clear transparency in many of the smaller ones.

Crystallography.—The crystals are of one type only, being prismatic or slender acicular in habit. They occur in three ways: (1) as separate individuals, (2) in radiating groups, or (3) in tapering barrel-shaped aggregates. In some instances the minute radiating crystals, crowded together over the surface, possess a moss-like appearance. The needles may attain a length of an inch or more, but those having faces sufficiently bright to permit measurement with any degree of accuracy are of almost microscopic dimensions. As the crystals are very brittle and easily broken, it was a matter of some difficulty to obtain specimens with terminal faces. In small, well-protected pockets a considerable number were found, and about forty-five were studied carefully on the two-circle goniometer of the Goldschmidt type.

Pyromorphite belongs to the hexagonal-bipyramidal class. The forms observed by me are as follows:–

$c\ \{0001\}$, $m\ \{10\bar{1}0\}$, $a\ \{11\bar{2}0\}$, $x\ \{10\bar{1}1\}$, $y\ \{20\bar{2}1\}$
$\pi\ \{40\bar{4}1\}$, $\epsilon\ \{30\bar{3}4\}$, (See fig. 1)

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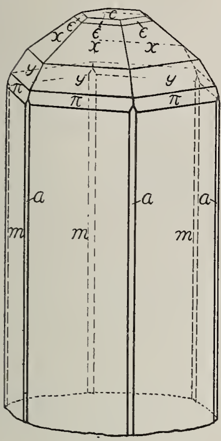
[*] The data contained in this paper were embodied in a thesis accepted by the University of Toronto for the degree of Master of Arts.

The basal pinacoid, *c* $\{0001\}$, is very poorly developed. Reflections could be obtained from it on only five of the crystals studied. On many of the crystals it was so rough and uneven that it appeared to be merely a fracture surface.

FIG. 1.



The prism of the first order, *m* $\{10\bar{1}0\}$, is the most prominent form on all crystals, and is usually represented by well-reflecting surfaces, from which satisfactory readings may be obtained. These faces commonly exhibit minute longitudinal striations.

A very important fact which has not, to the writer's knowledge, been as yet observed is to be noted in connection with the prismatic faces. They do not exhibit an absolute parallelism, but converge slightly toward the upper end of the *c* axis. From this it would appear that the symbol $\{10\bar{1}0\}$ is only approximately correct, the true prism faces being replaced by vicinal planes which depart from the theoretical position of the real prisms by a definite measurable angle. Only in exceptional cases are true prism faces present, for almost invariably they are replaced by these vicinal planes. The readings for all the faces in the prismatic zones of twenty-one crystals give a mean angle of 89° 33′ between the normal and the vertical axis. The Miller symbol thus becomes $\{135\cdot\ 0\cdot\ \bar{1}\bar{3}\bar{5}\cdot\ 1\}$. The frequent recurrence of these faces, indicating an approximately constant deviation from the theoretical value, gives weight to the theory of S. M. Websky,* that vicinal planes are not accidental, due to distortion of the crystal, but that they follow some definite law which has its foundation in the internal molecular arrangement. In the table of angles it will be noted that the other forms show considerable variation from the calculated values also, but it must be remembered that the values for these forms were obtained from poorly reflecting surfaces, while in the case of the prism faces well-defined images were obtained.

The prism of the second order, *a* $\{11\bar{2}0\}$, was observed on two crystals only, the faces being very narrow, and in some instances curved. As shown by the table on page 42, the readings are, however, sufficient to indicate that the faces are undoubtedly prisms of the second order.

The unit bipyramid, *x* $\{10\bar{1}1\}$, is the most prominent of all the pyramidal forms. The faces are in most cases very dim,

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* Zeitschr. d. d. Geolog. Ges., xv, p. 677, 1863.

and on the goniometer give no distinct signals. The bipyramid $y\ \{20\bar{2}1\}$ was found on three crystals only, and in each case the faces were very indistinct. They are proportionally very much smaller than the faces of the unit bipyramid. The bipyramid $\pi\ \{40\bar{4}1\}$ was observed with very narrow edges on one crystal only. As no distinct images could be obtained from these faces, several readings were taken, and the results averaged.

The bipyramid $\epsilon\ \{30\bar{3}4\}$ is a new form. It was represented on six of the crystals, and, though the faces are extremely minute, the averages of a large number of readings approximate to the theoretical values so nearly that the form is established with certainty. The average reading of four of the best faces gives a value 32° 28′ for the angle ρ, the calculated value being 32° 31′. A form having this symbol is recorded for apatite, which also belongs to the hexagonal-bipyramidal class. The bipyramid of the second order, $s\ \{11\bar{2}1\}$, is the only form recorded by Dana or Goldschmidt which finds no representation on these crystals.

All forms observed by me, as well as those given by Dana, together with their calculated and observed angles, are indicated in the following table :

TABLE OF ANGLES.

	Forms		ρ		ϕ	
	Dana	Bowles	Observed	Calculated	Observed	Calculated
c	$\{0001\}$	$\{0001\}$	0° 09′	0°	-- --	-- --
m	$\{10\bar{1}0\}$	$\{10\bar{1}0\}$	90° 03′	90°	0°	0°
		Vicinal	89° 33′	-- --	0°	-- --
a	$\{11\bar{2}0\}$	$\{11\bar{2}0\}$	90° 07′	90°	30° 04′	30°
x	$\{10\bar{1}1\}$	$\{10\bar{1}1\}$	40° 37′	40° 22′	0° 13′	0°
y	$\{20\bar{2}1\}$	$\{20\bar{2}1\}$	59° 16′	59° 32′	0° 13′	0°
π	$\{40\bar{4}1\}$	$\{40\bar{4}1\}$	74° 07′	73° 37′	0° 06′	0°
s	$\{11\bar{2}1\}$	------	-- --	55° 49′	-- --	30°
ϵ	------	$\{30\bar{3}4\}$	32° 28′	32° 31′	0° 07′	0°

Chemical Analysis.—As extremely pure crystals of both the yellow and green varieties were at hand, it seemed advisable to make an analysis of each in order to obtain if possible some adequate explanation for the variation in color. The chemical analysis was, in general, based on the method outlined by Medicus.* The results are as follows :

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* Chemische Analyse ; Kurze Anleitung zur Gewichtsanalyse, Dritte Auflage, p. 91, 1897.

	Yellow Variety	Green Variety
PbO	80·20%	80·13%
CaO	0·59	0·56
FeO	0·86	0·46
P_2O_5	16·12	15·65
As_2O_5	0·41	0·90
Cl_2	2·52	2·59
CaF_2	trace	----
Insol.	0·08	0·05
	100·78	100·34
Less oxygen equivalent of Cl	0·57	0·59
	100·21	99·75

Although there is considerable difference to be observed in the results of these two analyses, such as the striking variation in the amounts of iron and arsenic, it can, nevertheless, be shown that the analyses are to be relied upon; for if the molecular ratios are calculated from the above determination, it will be seen that in each case the results point to the generally accepted formula for pyromorphite.

	Yellow Variety Molecular Ratios			Green Variety Molecular Ratios		
	I	II	III	I	II	III
PbO	0·324	0·346	9·03	0·323	0·340	8·95
CaO	0·010			0·010		
FeO	0·012			0·007		
P_2O_5	0·013	0·115	3·00	0·110	0·114	3·00
As_2O_5	0·002			0·004		
$PbCl_2$	0·036	0·036	0·94	0·037	0·037	0·98

Since the combined molecular ratios of the oxides of lead, calcium, and iron, and the pentoxides of phosphorus and arsenic, are almost exactly in the proportion 3 to 1, we may assume that those values are very nearly correct. Hence if we give to the combined ratios of the pentoxides of phosphorus and arsenic the value 3, we obtain the simplified ratios in columns III. In each case these are approximately 9 : 3 : 1, which, as remarked above, is in close agreement with the generally accepted formula $9PbO.3P_2O_5.PbCl_2$, or in more simplified form $Pb_5Cl(PO_4)_3$.

In some cases the green color has been accounted for by the presence of a small amount of copper, but here no trace of copper is to be found. Leonhard* states that the yellow

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* N. Jahrbuch für Min. und Geol., 1867, p. 449.

variety differs from the green only in its smaller content of arsenic. He records an analysis which indicates that the green pyromorphite contains 0·66 per cent arsenic pentoxide, while the yellow variety contains none. The analyses given above show a somewhat similar relationship; for, although arsenic is present in both, there is a larger per cent in the green variety. This fact, and the presence of a larger quantity of iron oxide in the yellow variety, are the only marked differences brought out by the chemical analyses.

Specific Gravity.—This was determined by means of a Muthmann capillary-tube pycnometer. Extremely pure material of both varieties was obtained, and a comparatively large amount (about eight grams) was used, in order to insure accurate results. Crystal fragments about the size of fine shot were employed. Several determinations were made, and the results are tabulated below:

	Yellow Variety	Green Variety
I	7·011	7·055
II	7·016	7·052
III	7·012	7·046
IV	7·014	7·053
Average	7·013	7·051

From the above results it is evident that the green pyromorphite has a higher density than the yellow. Dana* gives the specific gravity of the pure mineral a rather wide range, varying from 6·5 to 7·1. This British Columbian pyromorphite then approaches the higher limit set by Dana. The results obtained are slightly higher than those of Bauer,† who gives a variation of 6·9 to 7·0.

In conclusion I desire to acknowledge valuable assistance rendered by Prof. T. L. Walker of the University of Toronto, under whose direction the investigations were conducted. I am indebted to Prof. W. A. Parks of the same institution for selecting the material, and for information regarding its occurrence and associations.

Mineralogical Laboratory, University of Michigan,
Ann Arbor, Mich., March 8th, 1909.

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* System of Mineralogy, p. 770.

† Lehrbuch der Mineralogie, 2te Auflage, 1904, p. 805.

Art. VIII.—*On the Application of the Term Laramie;* by A. C. Peale.

Two publications* by Mr. A. C. Veatch "On the Origin and Definition of the Geologic term Laramie" seem to me to call for notice because of an apparent misapprehension on the part of Mr. Veatch of the origin of the name Laramie and as to its use especially at the time it was given. It is also the more necessary to come back to the original definition and application because so many geologists and paleontologists have applied the name to beds that do not fall within the limits of the definition. That corrections can now be made is largely due to the discovery by Mr. Veatch in the Carbon and Evanston regions of Wyoming of an unconformity just above the beds that should be correctly referred to the Laramie in accordance with the original definition, thus repeating west of the Front Range of the Rocky Mountains the discovery made by Cross and Eldridge of the Post-Laramie break east of the mountains in Colorado in 1888† and reiterated by them in 1896.‡

What I wish to show in this paper is, first, the original use of the name Laramie; second, why the original name should hold to-day just as when first defined; third, that the conclusions of Mr. Veatch, based as I think upon false premises, are not verified by the facts; and fourth, that a new name is not necessary even according to Mr. Veatch's own supposed evidence.

As a member of the Hayden Geological Survey at the time the term "Laramie" was first proposed and used by both the Hayden and the King organizations, and as one of those who first used it, a statement of my recollection may be of some interest here. Just at the time the work of the Exploration of the 40th Parallel, under Clarence King, was approaching completion, and their geological maps were being colored, the work of the U. S. Geological and Geographical Survey of the Territories had also reached the stage when it became necessary to color the maps of Colorado, upon which field work was begun in 1873 and finished in 1876. As two of the maps of the former organization adjoined the work of the Hayden Survey along the northern line of Colorado, it was deemed desirable that there should be some correlation, in terms at least, where the work joined. There was substantial agreement as

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* This Journal, vol. xxiv, pp. 18–22 (an abstract), July, 1907; and Jour. of Geol., vol. xv, pp. 526–549.

† Proc. Colo. Sci. Soc., vol. iii, p. 97.

‡ U. S. Geol. Survey Monograph, vol. xxvii.

to most of the formations, about the only difference being as to the age of the beds resting conformably upon the Fox Hills Cretaceous of Hayden as exposed along the line of the Union Pacific Railway and to the eastward of the foothills of the front range of Colorado, where they were usually designated by Hayden and the members of his survey as the lignitic beds of eastern Colorado or the lignitic coal group of the eastern slope. These beds were considered by King to be of Cretaceous age, while Hayden was inclined to consider them as belonging to the Tertiary. At this time Clarence King wrote* to Dr. Hayden asking him to propose a name for these debatable beds—debatable only as to age, for both agreed. as to their stratigraphic position. In reply to this letter Hayden suggested the name *Laramie*, which was accepted by King as indicated by him on page 331 of the volume on Systematic Geology† where he says: "During the slow gathering of the evidence which shall finally turn the scale, I proposed to Dr. Hayden that we adopt a common name for the group, and that each should refer it to whatever age his data directed. Accordingly it was amicably agreed between us that this series should receive the group name of *Laramie*, and that it should be held to include that series of beds which conformably overlies the Fox Hills."‡

In accordance with this, in coloring the geological map of Colorado we designated the beds above the Fox Hills as Laramie and in referring to their age called them Post-Cretaceous. There was no type locality so far as we were concerned, nor was there any such idea in the mind of Hayden. He proposed the name partly because it was a euphonious name and a broad one as he conceived it, the beds outcropping not only in the Laramie plains but also on both sides of what was then sometimes known as the Laramie range, and also in the vicinity of the Laramie River. It was also proposed by him partly out of compliment to Clarence King, who was then working in what Hayden termed the Laramie plains, he using the term in its very broadest sense as reaching from the Laramie Range to the Wahsatch Range.§

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* Clarence King's letter was found by the writer among the papers of Dr. Hayden after his death. The name Laramie does not occur in it.

† U. S. Geological Exploration of the 40th Parallel, vol. i, 1878.

‡ Dr. C. A. White, in an interview (March 24, 1909) with the writer, confirms the statement as to the origin of the name Laramie and says further that the last time he talked with Dr. Hayden the latter protested against his (White's) having once used the term "The Laramie Group of *King*," when he (Hayden) was the author of the name.

§ "This great area [Laramie Plains] might be called a park; it is enclosed on three sides by extensive mountain ranges, but on the west its limits are not well defined, inasmuch as no mountain ranges of any importance intervene until we come to the Wahsatch Range in Utah."—Report U. S. Geological Survey Wyoming for 1870 (1871), p. 121.

He also believed that the "area for the solution of the question [the relations of the well-defined Cretaceous group with the Lignitic] lies in the Laramie plains and westward towards Salt Lake."* It was intended that the name should cover all localities in which the beds occurred. If any localities should be considered as typical localities they would be those mapped by us along the Front Range in eastern Colorado, and by King along the Range in Wyoming. That Clarence King had no type localities of the Laramie plains in his mind is also evident from the fact that immediately following his definition of the Laramie he gives as localities of its occurrence the following in eastern Colorado, just north of the area in which the Hayden Survey was at work:

Parks Station, Colorado,
6 or 7 miles west of Carr's Station, Colorado,
West of Greeley, Colorado,
Crow Creek, Colorado, and
Platteville, Colorado.

These are followed by references to "good exposures of Laramie" east of Separation, and at other localities along the line of the Union Pacific and in northwestern Colorado.†

King refers to the exposures in Colorado as follows: "The upheaved sedimentary rocks along the eastern foothills of Colorado Range offer several admirable sections from the base of the Cretaceous far up into the series, and these exposures have formed the subject of continued study by Dr. F. V. Hayden and the late Prof. F. B. Meek. The section, as elaborated by them, has been constantly re-observed by us with such concurrence of result that we have cheerfully adopted their nomenclature from the base of the series up to the summit as defined by them."‡

King, after summarizing the Cretaceous series as defined by Meek and Hayden up to and including the Fox Hill Group, says: §

"Here, with those who follow Hayden, the Cretaceous series comes to an end. Conformably over this [Fox Hill Group] lies the group which Hayden and I have agreed to call the Laramie, *which is his Lignitic Group*, and is considered by him as a transition member, between Cretaceous

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* Ann. Rpt. U. S. Geol. and Geograph. Surv. of the Territories for 1873 [1874], p. 26.

† It is interesting to note that Carbon, Wyoming, does not appear in the list, and that Carr's Station is only about 24 miles east of the lower end of the Laramie hills, while the other localities are within short distances to the east and southeast of the mountains.

‡ U. S. Geol. Expl. 40th Parallel, vol. i, Systematic Geology, p. 297.

§ Geol. Expl. 40th Parallel, Systematic Geol., vol. i, p. 348.

and Tertiary. There is no difference between us as to the conformity of the Laramie Group with the underlying Fox Hill. It is simply a question of determination of age upon which we differ."

The italics in this quotation are my own. King is in error as to the inclusion in the Laramie by Hayden of the Fort Union or of all the lignitic beds. Hayden's last word on the subject is the following:*

"If objection is made to the use of the term 'Lignitic' Group I would say that, in this work, it is restricted to a series of coal-bearing strata lying above the Fox Hills Group, or Upper Cretaceous, and these are embraced in the divisions Laramie and Fort Union Groups. It is well known that there are in various parts of the West, especially along the fortieth parallel and southwestward, very thick beds of coal in the various divisions of the Cretaceous, extending down even into the Upper Jurassic. Had this not been the case, the more general term Lignitic would have been retained by this Survey in preference to any other." "It is also probable that the Wahsatch Group as now defined and the Fort Union Group are identical as a whole, or in part at least."

Historically we find the first mention of the term Laramie in an author's proof of a Geological map No. II of the 40th Parallel Survey by Clarence King and S. F. Emmons. This map was dated November 15, 1875, and noticed in this Journal, 3d series, vol. xi, No. 62, p. 161, Feb. 1876. But neither on the map, which covers the Green River Basin, nor in the notice, is there any definition of the term. On the map certain areas are colored to represent the formation beginning with the region to the west of Oyster Ridge, including the vicinity of Rock Springs, Point of Rocks, and Black Buttes, and extending on the east to Creston and a narrow strip of country reaching southward from that station of the Union Pacific Railroad. On the southern part of the map are several small areas adjacent to the Uinta Mountains that are also referred to the Laramie. It is noticeable that *Carbon* is not included within the limits of the map. This map is referred to by Hayden in his "Notes on some Artesian Borings along the line of the Union Pacific Railroad in Wyoming Territory,"† in which article for the first time he uses the term *Laramie*, which he does in strict conformity with the coloring of King's map, which he evidently had before him as he wrote.

In this article also Hayden repeats his division of the Tertiary into four series as laid down in his report for 1870 (p. 74), the first two being the following:

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* Report U. S. Geol. Survey of the Territories, Tertiary Flora, 1878, p. iv, also p. v.

† Bulletin U. S. Geol. and Geograph. Survey of the Territories, vol. iii, No. 1, pp. 181–185, April 5, 1877.

"*First Series.*—The coal strata, Lower Eocene, characterized by numerous impressions of deciduous leaves, marine and fresh water *Mollusca*.

Second Series.—Arenaceous, Upper Eocene, characterized by a profusion of fresh water shells, as *Unio*, *Goniobasis*, *Viviparus*, *Lymnaea*, etc. and a portion of these being casts."

On the next page, he says "The first series is the Laramie or Lignitic Group; the second, the Wahsatch or Vermillion Creek group, the former name having the priority, and having been attached to the great group of reddish sands, clays, and conglomerates, west of Fort Bridger in 1870. This group has been found to extend southward through western Colorado into New Mexico."*

As just noted, Hayden considered the Wahsatch and Fort Union to be identical in whole or in part, a position that Dr. Knowlton informs me was verified by him by his field studies in 1908. In the diagrammatic section accompanying his paper Hayden shows the *Laramie* divided into two groups resting upon the Fox Hills.

The next one to use the term was Dr. C. A. White,† who in the same volume of the Bulletin gives two generalized sections; one of the Green River Region, in which he places the Laramie Group in its proper place above the Fox Hills Cretaceous, and the other a section in the Upper Missouri River region in which the Laramie does not occur, but in which the Judith River Group is placed between the Fox Hills and the Fort Union.

In the descriptive Geology, vol. ii, of the Reports of the Geological Exploration of the 40th Parallel, which bears the imprint of the year 1877, Mr. Arnold Hague gives on page 60 the first *printed description* of the Laramie, beginning: "The Fox Hill strata pass by imperceptible gradations into the Laramie series, offering no well-defined lines of separation, both formations from top to bottom consisting of coarse sandstone." Mr. Hague, after describing the geology of the Cretaceous plains of Colorado, on the succeeding page (61) presents the first section ever published of the Laramie which was measured at the extreme northern limit of the Laramie formation about 18 miles southwest from Cheyenne, and 5 or 6 miles west from Carr Station on the Denver Pacific Railroad.

This section, if any should be so considered, would be the typical Laramie section. Other Laramie localities east of the Colorado Range and the Laramie hills he describes in following pages. When Hague described the Carbon Basin it is evident from the description (pp. 143–148) that considerable

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*U. S. Geol. and Geograph. Surv. Ter. Bull., vol. iii, p. 184.

†Ibid., No. 3, pp. 608, 609, May 15, 1877.

doubt existed in his mind as to the exact age of the beds exposed at Carbon. On p. 144 he says "In determining the true horizon of these beds, however, it is necessary to trace out their relations with the great sandstone formation, which forms all the higher ridges of the region, and to compare the strata with other similar localities of Laramie or supposed Laramie described in the remaining portions of the Report. In the Annual Report for 1876 of the U. S. Geological and Geographical Survey of the Territories, published in 1878, the reports of the geologists, which were prepared during the year 1877, all contain the term Laramie and the beds are represented and so named on the maps in the atlas of Colorado which bears the imprint of 1877 although not actually issued until 1878.*

The Atlas of the 40th Parallel Survey, on which the Laramie is also shown, bears the imprint of 1876, but was not issued until a later date† (1877 or 1878?).

It is evident, therefore, that the term came into use in both the King and the Hayden organizations at about the same time.

Having given the facts as to the name and original use of the name "Laramie," I now wish to show that the definition holds just as good to-day as when made and that, notwithstanding the mistaken application of the term to beds of older as well as of more recent age, there still remains the set of beds to which the name of Laramie was originally applied and to which no other name can logically be applied. As to the age of the beds we are not primarily concerned in this place. As Dr. G. M. Dawson said nearly thirty-five years ago,‡ "much of the difference of opinion" . . . . . . "appears to have arisen from approaching the problem with preconceived ideas, and the attempted application of paleontological generalizations derived from the study of other localities, which have been formulated under too rigid laws." The confusion in the use of the name is due mainly to the fact that not only have the paleontological collections been too meager, but that the stratigraphical relations have been misunderstood. Beds of various ages have been mistakenly correlated as of Laramie age without the confirmation of paleontological evidence, although we now know that both stratigraphically and paleontologically they are utterly different. Thus the beds at Point

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* Catalogue of Publications of the U. S. Geol. and Geograph. Surv. of the Territories, 3d edition, p. 50, 1879.

† Both the Hayden and King Atlases are reviewed in this Journal, 3d series, vol. xv, May, 1878, King's on p. 396 and Hayden's on p. 397. The former is said to have been "recently issued" and the latter "just issued."

‡ Geol. and Resources of the Region in the vicinity of the Forty-ninth Parallel, 1875, p. 184.

of Rocks, Wyoming, supposed by King to be of Laramie age, were shown by Stanton* to belong to Montana. Cross and Eldridge in 1888 described an unconformity above the Laramie in the Denver Basin in Colorado and restricted the term Laramie in accordance with its original definition to the beds resting conformably upon the Fox Hills Cretaceous. The Judith River beds, referred at one time or another to all the formations from the Jurassic to the Fort Union, were finally, in 1903,† referred by Stanton and Hatcher to the Upper Cretaceous (Montana formation). More recently part of the coal beds of the Raton Mesa region, studied by Mr. W. T. Lee,‡ have been found to be above an unconformity which apparently occupies the position of the break found by Cross and Eldridge above the Laramie in the Denver Basin. Mr. Veatch in his generalized section§ in Carbon Co., Wyoming, shows an unconformity separating 6500 feet of beds, which he calls "Lower Laramie," resting conformably upon the Montana formation, from 6000 feet of beds (called "Upper Laramie" by him) lying conformably beneath strata of Fort Union age. The beds just below the unconformity are devoid of plant remains so far as known at present. There certainly is room here for the Laramie formation and the probabilities are that eventually plants will be found in them and enable us to settle the question of their age. The beds above the break and between it and the Fort Union are in the Shoshone group as named by Cross.‖ More recently Dr. F. H. Knowlton¶ has determined the Fort Union age of the Dinosaur (Ceratopsia) bearing beds lying below the well-defined and almost universally recognized Fort Union, by the identification of a typical Fort Union flora associated with dinosaur bones. Knowlton has also referred to the fact that the "Upper Laramie" or Paskapoo beds of the Canadian geologists are the equivalent of the upper Fort Union and that probably their "Lower Laramie" or Edmonton beds should be correlated with the lower Fort Union, as both of the latter also contain associated Fort Union leaves and dinosaurian remains.** None of these supposed Laramie beds of the Canadian geologists apparently conforms to the original definition.†† It is doubtful if any beds of true Laramie age

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*Science, N. S., vol. xviii, pp. 211, 212, 1903.

†U. S. Geol. Surv., Bull. No. 257, 1905.

‡Lee, Bull. Geol. Soc. Amer., vol. xx, 1909 (in press).

§This Journal, vol. xxiv, p. 18, July, 1907; also in Journal of Geology, vol. xv, pp. 526–549, 1907.

‖Proc. Washington Acad. of Sciences, vol. xi, pp. 27–45, March 31, 1909.

¶Knowlton, Proc. Washington Acad. of Sciences, vol. xi, p. 179 *et seq.*

**See, also, Geol. Surv. of Canada, Annual Report, vol. ii, for 1886, p. 132, E. If not Lower Ft. Union, they may possibly be Shoshone.

††McConnell in Geol. Surv. of Canada, Ann. Rept. for 1885, vol. i, 1886, p. 46 C, refers to the "Lower Laramie" as resting sometimes on the Pierre shales but as occurring more often with Fox Hills beds intervening.

occur in this region. In view of all these erroneous correlations, inevitable though the mistakes were, and in view of the present widely different application of the term as used by various authors, it becomes absolutely necessary that we should return to the original definition and confine the name Laramie to the beds that fit the definition and apply it now and in the future only to such beds. This is all the more necessary inasmuch as the Laramie beds in the original or typical areas in Colorado east of the Front Range, although restricted in thickness by Cross and Eldridge in taking from the upper part (from above the break) the Arapahoe and Denver, are characterized by a flora in which Dr. Knowlton recognizes 123 species, of which only 17 are common to the Laramie and the Montana formations and 21 to the Laramie and the Denver. These beds also contain an invertebrate fauna of about 25 species of fresh and brackish water shells.*

As already noted also, there is according to Veatch a series of from 4000 to 6500 feet of beds in the Carbon and Evanston areas on the Union Pacific Railroad which occupy the stratigraphic position of the Laramie above the Fox Hills, but which up to the present time are not known to contain any fossil plants† but do have some fresh and brackish water shells which alone are inconclusive as to the age of the beds.

After his introduction and a brief account of the confusion in the present use of the term Laramie with a statement of King's views, Mr. Veatch gives his idea as to the boundaries of the Laramie Plains based mainly upon descriptions by Prof. Cyrus Thomas and Mr. Arnold Hague, and acknowledges that the name has been applied in both a restrictive and a broad sense, crediting Hayden with having used it in both ways. Mr. Veatch then devotes seven pages to Hayden's investigations, in which he quotes Hayden's views as to the "Lignitic Group," which is somewhat beside the question inasmuch as they relate to what Hayden thought at various times between 1867 and 1875, before the term Laramie was proposed. Then follow five pages detailing Hague's description of the Carbon area and discussion of the age of the beds there exposed, and a statement of "Cross's re-definition," after which he gives his summary and conclusions.‡ These conclusions are identical in his article and in the abstract in this Journal,§ and it is with these alone that we are concerned here.

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* U. S. Geol. and Geograph. Surv. of Territories, 11th Ann. Rept., 1879, pp. 165, 190, 253.

† In the Evanston area a few plants not specifically determinable have been found.

‡ The Journal of Geology, vol. xv, pp. 526–549, 1907.

§ This Journal, vol. xxiv, pp. 18–22, 1907.

Mr. Veatch's first conclusion,* that the name Laramie is derived from the Laramie Plains, and his definition of the Laramie Plains as extending from the Front Range to and slightly beyond the North Platte River, have already been considered in treating of the origin of the name on a previous page, when it was also shown that Hayden was in the habit of using the name in its broadest sense, comprising the entire country between the Front or Laramie Range and the Wahsatch Range.

The second conclusion,† that Carbon was a most important locality both paleontologically and economically is undeniably true; but, although colored on the map as Laramie, the age of the beds examined there was considered doubtful by King and his colleagues I have already shown. It was geologically considered by Hayden very much as by the members of the King Survey. He says,‡ "To the geologist this entire region (from Carbon to Rawlins) is one of great interest. Even up to the present time it is invested with much obscurity" . . . . . . "The beds are so complicated" . . . . . . "that it is difficult to unravel their relations."

That either Hayden or King had Carbon in mind as the locality of a type section of the Laramie, is apparently a pure assumption on the part of Mr. Veatch. Just as the geologists of the King Survey had considerable doubt as to the geological age of the beds of Carbon, although they colored them on the map as Laramie, so King in his discussion of the Laramie does not mention Carbon, nor does it appear to be mentioned in the volume (Systematic Geology, vol. i) and the name certainly does not appear in the index. The work of the Geological and Geographical Survey of the Territories did not include Carbon, which was within the limits covered by the Survey of the 40th Parallel, and all the work done there by Hayden and his collaborators was simply in the way of reconnaissance work and of the most general character.

The third conclusion of Mr. Veatch§ contains three statements that the facts scarcely warrant: first, that "It was the practice of the Hayden and King surveys to name formations and groups from localities where the beds were regarded as typically exposed"; second, that "the name Laramie was proposed and adopted as an exact synonym of Hayden's Lignitic as defined by him in Wyoming and Colorado," and third, that "the type locality of the Laramie is Carbon on the Laramie Plains."

Mr. Veatch himself acknowledged that "King used Green River, Bridger, Uinta, Truckee, and other names without say-

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* This Journal, loc. cit., p. 19.

† This Journal, loc. cit., p. 19.

‡ Preliminary Rept. U. S. Geol. Survey of Wyoming, 1870 (1871), p. 134.

§ This Journal, loc. cit., p. 19.

ing the name was derived from such and such a locality." Hayden did not *always* give even names to the beds he studied, as when in his earlier work he gave numbers to his subdivisions of the Cretaceous. It was *not* therefore the *general* policy of the Hayden Survey to name geologic formations from any particular localities in which there were type sections. There is no more warrant for assuming that Hayden, when he suggested the name Laramie, had in his mind any type locality, such as Carbon as suggested by Veatch, than there is for assuming a type locality for the name Colorado, which was applied by Hayden to the three divisions of the Cretaceous—Fort Benton, Niobrara, and Fort Pierre—on account of their great variability in western Colorado and the difficulty of correlating them with their equivalents in eastern Colorado.* There was no type-section for the Wahsatch formation, the name applied by Hayden to the variegated sands and clays west of Fort Bridger and in the vicinity of Evanston. The Fort Union Group was the name given by him to beds exposed, not only in the vicinity of old Fort Union, but to those extending northward into the British possessions and southeastward along the Missouri River as far as Fort Clark and as exposed at various places in Wyoming. That there is no type section at old Fort Union I am prepared to say, after a personal examination of that region in 1907.

That the name Laramie was not used by Hayden as an exact synonym of Lignitic is evident from what has already been said under a previous heading, where it is noted that he included both Laramie and Fort Union under the term Lignitic—that is, Lignitic was the broader term.

Hayden's explorations began in the Upper Missouri Region in 1853, and although he knew at that time that coal existed in the Dakota group, for some time he regarded the entire Lignitic group (excluding of course the Dakota coal) as of Tertiary age. In 1868† he recognized the existence of coal beds extending into the Cretaceous, and in 1875, just before the introduction of the term Laramie, came to the conclusion that if a division of beds was based upon the presence of coal a readjustment would *necessarily follow*. He says:‡ "If it is true that, taking into view the entire Lignitic area of our western Territories, the coal beds are continuous in every division, from the Jurassic to the summit of the Upper Lignitic, we might make this general division: 1st, Lower Lignitic group, including all the Lignitic deposits of marine origin; 2d, Middle

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* U. S. Geol. Expl. 48th Parallel, vol. i, Systematic Geology, p. 298.

† Bull. U. S. Geol. and Geograph. Survey of the Territories, vol. i, No. 2, p. 1 B (prefatory note), 1876.

‡ Bull. U. S. Geol. and Geograph. Survey of the Territories, vol. i, p. 406, 1876.

Lignitic, embracing all deposits of brackish water origin; 3d, Upper Lignitic, including all beds of purely fresh-water origin. In my opinion, the first division would include all beds to the summit of the true Cretaceous; the Middle Lignitic embraces my Transition Series, or, if they are not admitted by geologists, I would insist upon their Lower Tertiary age. The Upper Lignitic, or fresh-water deposits, are of unquestioned Tertiary age". This makes it clear that Hayden did not intend to include in the Laramie all the beds he had previously referred to the Lignitic, not even his "Great Lignitic"—(Fort Union) being so included. The term Laramie was used by him and by all the geologists of his survey to include the beds resting immediately and conformably upon the Fox Hills. It was so used in the Reports of the Survey and in the Atlas of Colorado, as also by King and his colleagues in their reports and Atlas.

That Cross and Eldridge separated from the upper part of the Laramie formation, as colored in the Atlas of Colorado, the Denver and Arapahoe formations which were found unconformably resting upon the Laramie, and which they divided into an Upper and Lower division, in no way invalidated its existence; nor do mistakes in correlation in other localities of beds with the undoubted Laramie according to the original definition along the Front Range in Colorado, whether made by members of the Hayden Survey in southern and western Colorado, by King and his successors in Wyoming, or by the Canadian geologists who call the Fort Union beds Upper and Lower Laramie, destroy the validity of the term. It would matter little if no Laramie were found in central Wyoming below the great unconformity, where it may have been removed by erosion, or that we find that we have to extend the Fort Union downward and find it sometimes resting unconformably upon Fort Pierre Cretaceous without Laramie or even without Fox Hills beds beneath it. That we find in Colorado, Wyoming and Montana a series of beds to which local names have been given, such as Livingston, Denver, Arapahoe, Black Buttes beds, Evanston beds and Carbon beds, all of which lie above the great unconformity and below the Fort Union, and which cannot be correlated with either the Laramie or the Fort Union, is a good and sufficient reason to include them under the term Shoshone proposed by Mr. Cross.

It may be questioned whether the Black Buttes beds (Agathamus beds) should be included in Cross's Shoshone, but at the present time the preponderance of evidence apparently warrants such a reference. If the unconformity at the base of these beds noted by Meek and Bannister in 1872 and Powell in 1876* should be fully demonstrated, the beds certainly could

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* Geology of the Uinta Mountains, 1876, p. 72.

not be correlated with the Laramie. Professor Meek,[*] basing his opinion upon the study of the invertebrates, was inclined to consider the beds as of Tertiary age, the Dinosaurian remains alone indicating any other possible age for them. As to the plants found at Black Buttes there are twice as many species common to these beds and the Shoshone as are common to the Laramie and the Black Buttes beds, and we know now that Dinosaurian remains are not uncommon in the Shoshone. If it follows "irresistibly" from what Mr. Veatch has written that Carbon is the type locality of the Laramie, in my opinion it follows just as "irresistibly" from what is outlined in these pages that Carbon is not and never was the type locality.

Mr. Veatch's fourth conclusion[†] is that the Hayden and King parties at Carbon studied only the beds above the great unconformity that he, Mr. Veatch, has since determined, and that they considered them conformable to the Fox Hills, and therefore according to Veatch these beds above the break and these only should have the term Laramie. That King and Hayden thought the beds conformable certainly justified them in considering them at the time as Laramie in accordance with their own definition and does not militate against the reference to the Laramie of the beds below the break which were not subjected to the same minute investigation as the upper beds. As to "the absolute necessity of a type locality to afford the means of finally and conclusively correcting inaccurate statements or conclusions of the author or authors of a geologic name," we at least all agree upon the desirability of such a type locality, although we may disagree as to whether there is one in the present case. Mr. Hague's consideration of the Carbon locality has already been referred to.

The fifth conclusion[‡] of Mr. Veatch, that "the attempt to redefine the term Laramie from the exposures in the Denver region, some 200 miles from the type locality, is therefore not defensible," embraces several fallacies. In the first place there was no redefinition, and secondly, as we have shown, there is no specified type locality 200 miles from the Denver region. If there were such a type locality the Denver region would naturally be a part of it as already shown. No redefinition of the Laramie was made by Cross and Eldridge when they restricted it by taking from above it the Arapahoe and Denver. No redefinition was necessary because of their discovery of the unconformity at the base of the Arápahoe, for the Laramie, although not so thick as first supposed, was still left below, and was still conformable to the underlying Fox

[*] U. S. Geol. Surv. of the Territories for 1872, 1873, pp. 529, 530.

[†] This Journal, loc. cit., p. 20.

[‡] This Journal, loc. cit., p. 20.

Hills, and the original definition still held good and would hold, though only a few feet of beds had been left in that stratigraphic position.

In his sixth conclusion* Mr. Veatch says, "while strictly speaking the name Laramie can be applied appropriately only to the upper beds (Upper Laramie) and it cannot with any propriety be restricted to the lower beds (Lower Laramie), the consideration that it was proposed for the beds between the Wahsatch and the Marine Montana Cretaceous and has been most commonly and extensively used in this broad sense, has led to the suggestion that the retention of the name in the original sense will cause the least confusion, and that it therefore might be expedient to define the Laramie as that series of beds occurring between the Marine Montana Cretaceous and the Fort Union".

In the first place Mr. Veatch is not warranted in using the terms Upper and Lower Laramie for his beds, as the Canadian geologists have used these terms since the early eighties (although they have misapplied them). It is manifestly an incongruity to include in the Laramie a marine or brackish water series and a fresh-water series which are separated from each other by an unconformity involving, as Veatch says, 20,000 feet of strata. As repeatedly shown in this article, the original definition of the Laramie covers only the beds resting *conformably* upon the Fox Hills. It was *not* proposed for the beds between the marine Cretaceous and the Wahsatch, and if any of the Fort Union or its underlying beds were included, it was with the mistaken idea that the latter were conformable to the Cretaceous beds below. Veatch's redefinition of the term would cause more confusion by far than by maintaining the original definition and including in the Laramie beds only the beds below the unconformity, resting conformably upon the Fox Hills.

Bearing in mind the fact that Veatch always uses the name Lower Laramie as the designation of the beds lying below the great unconformity, I contend that even according to his own presentation of the matter the term Laramie should apply to them alone and that no new name is necessary. He says†: "There are reasons for believing that the enormous development of Lower Laramie beds in the western part of the Laramie Plains" . . . . . more completely represents the Laramie deposition than at any other point." Why not therefore keep the term Laramie for them so long as they coincide in stratigraphic position with the beds that we know paleontologically and stratigraphically to be Laramie east of the Colorado or Front Range?

* This Journal, loc. cit., p. 20.

† This Journal, vol. xxiv, p. 21, July, 1907.

Before concluding this paper the following point should first be emphasized, viz., the importance of Mr. Veatch's discovery of the great unconformity lying above the Laramie, a discovery the value of which can hardly be overestimated. As he himself says: "The discovery of this great unconformity at all points that have been critically examined over an area of 1000 miles north and south and 250 miles east and west; the fact that it occurs on both sides of the Front Range of the Rocky Mountains, and its great magnitude, all make it one of the most important mile posts in the geological history of western North America. All these considerations suggest anew the first conclusion of Cross in the Denver Region, that this unconformity marks the dividing line between the Cretaceous and Eocene in this region." Equally important with this work of Veatch and of Cross is the identification by Knowlton* of the lower Fort Union—the Dinosaur-bearing beds of the Upper Missouri Yellowstone Region—and their more southern extensions in Wyoming and the Dakotas. The misapplication of the term Laramie to these lower Fort Union beds of Knowlton and to the Shoshone beds of Cross was, as already said, inevitable so long as we were in ignorance of this great unconformity and the entire series was supposed to be conformable.

The one conclusion we come to from what has been detailed in this paper is the following, viz., the name *Laramie* should be used only in accordance with the original definition of King and Hayden and be applied only to the beds resting conformably upon the Fox Hills Cretaceous. Whenever we find beds in this stratigraphic position they should be so referred, especially if they contain a Laramie flora, as noted in the original Laramie beds east of the Front Range in Colorado, where there is also an invertebrate fauna comprising at least twenty-five species of shells.

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* Proc. Washington Acad. of Sciences, vol. xi, p. 179 *et seq.*

Art. IX.—*Descriptions of New Genera and Species of Starfishes from the North Pacific Coast of America*; by A. E. Verrill.

[Brief Contributions from the Museum of Yale University, No. LXX.*]

The species here described were mostly received from the Canada Geological Survey; from the Provincial Museum of British Columbia, through Mr. C. F. Newcombe; from the U. S. National Museum; and from Prof. Kincaid, Washington State University. More detailed descriptions and illustrations have been prepared for publication in a General Report on the Starfishes of that coast, from San Francisco to the Arctic Ocean, which the writer has been engaged upon for several years, and has recently completed, but its publication may be somewhat delayed.

The littoral and shallow-water starfishes are probably more abundant on the coasts of British Columbia and southern Alaska than in any other part of the world. Of Asteriidæ alone, there are at least 40 species, besides many named varieties; of Solasteridæ six species are recognized; of Pterasteridæ seven species. A remarkable peculiarity is the number of species having six or more rays, even in groups that are commonly 5-rayed.

Solaster galaxides Verrill, sp. nov. Figures 2, ~~2a~~.

A broad-disked species, usually with nine or ten rays, covered above with very small crowded pseudopaxillæ, and resembling *S. endeca* in form and color.

Two typical specimens from Victoria have been received from the Provincial Museum of British Columbia. Both have nine rays. The larger has the radii 40 and 110^{mm}; ratios about 1 : 2.7. It was orange in life.

There are usually two subequal, rather long, acute, divergent furrow-spines on each adambulacral plate; only one distally. On the actinal surface the curved transverse row or comb has usually seven or eight graded spines, the two inner decidedly longer and stouter. The marginal spines are about as in *S. endeca*, but the infero-marginals are more elongated transversely, and bear a decidedly greater number of more minute spinules.

The synactinal series of pseudopaxillæ extends only to about the basal third of the free part of the ray. They are relatively smaller than in *endeca*, being here only about half the

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* By an unfortunate error the Nos. LXVII and LXVIII of this series were duplicated.

size of the infero-marginals proximally. The actinal interradial areas are apparently relatively larger than in *endeca* and bear a larger number of compressed pseudopaxillæ, the larger ones similar to the infero-marginals and synactinals. They form about sixteen radial rows, the smaller one in the median rows distally. They are covered with a large number of small, rather short regular spinules.

The oral and jaw-spines are much better developed than usual. The four apical spines are very large, strong, and acute. There are six graded furrow-spines on each side. The epioral spines are long and slender. They form two subparallel rows of about eight or nine graded spines. The spines in the opposed rows are often bent toward each other and interlocked. The two most adoral are distinctly larger than the others.

Fig. 1.

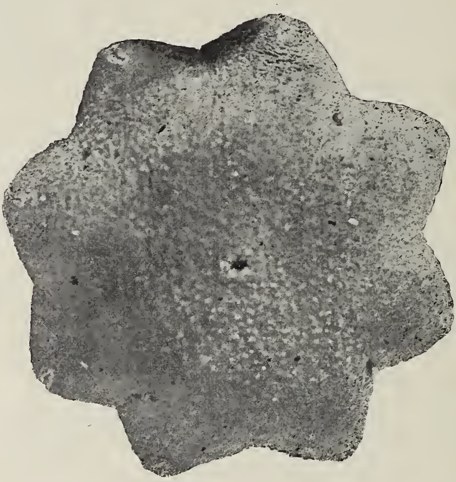

Fig. 1.—*Pteraster octaster* V. Dorsal side ; ⅔ nat. size.

Solaster constellatus Ver., sp. nov. Figures 3, 4.

An 8-rayed species with a small disk and long tapered arms. Radii are 21 and 78^{mm} ; ratios, 1 : 3.7.

The dorsal pseudopaxillæ are decidedly larger than in *Stimpsoni* V., which it somewhat resembles. They are stellate in form and usually, where largest, on the disk and base of rays, they have a single central and about six equally spaced and webbed marginal spinules, which are often fully expanded and nearly horizontal, producing the appearance of a sixpetaled flower; the largest ones may have seven or eight divergent spines, and the small distal ones only four or five; the supero-marginal and actinal ones are quite similar. The infero-actinal plates bear a larger number (8–12) of similar spinules. The adambulacral spines consist of a furrow-series with two or sometimes three rather short, tapered spines, and an outer comb of six or seven nearly equal, tapered spines, webbed nearly to the tips; the inner ones are usually rather longer, so that the rows are a little graded. Adoral spines strongly graded, about ten to a jaw, the apical ones unusually stout. The type is from Puget Sound (Prof. Kincaid). This is the only 8-rayed species known to me from that coast. Its large and beautifully stellate paxillæ are distinctive.

Pteraster octaster Ver., sp. nov. Figure 1.

Disk large and plump; margins well defined by points of actino-marginal spines; rays eight, short, about as wide as long, subacute; the ambulacral grooves turn up but little at the tips. Radii of the largest example, 20 and 30^{mm}.

Dorsal surface covered with a thick membrane through which the tips of the spinules show but little as pretty uniformly scattered points; in alcohol they form the apex of small, low, conical, fleshy elevations. Central oscule small, in alcohol inconspicuous, its short spines covered by a soft membrane. Ambulacral feet large, in two rows.

Adambulacral spines form combs of five or six spines, of which the innermost is much smaller and more slender than the rest, which are rather stout, tapered, subacute, divergent; the outer ones longer; the outermost appressed to the surface. Epioral pair of spines long and rather stout, tapered, translucent distally. The interradial areas are narrow, with rows of long, stout, imbedded actino-marginal spines, the ends of which project a little at the margin of the disk. Four specimens were sent to me by the U. S. National Museum. Three were from Bering Island, collected by Dr. Stejneger and Mr. N. Grebnitsky in 1888. One was from Kamchatka, collected by N. Grebnitsky.

This is the only *Pteraster* known which has more than six rays and is therefore easily recognized.

Pteraster hebes Ver., sp. nov.

Disk plump and relatively large, the five rays being very short and blunt, with the ambulacral grooves and plates turned upward and reflexed upon the upper surface nearly to the base of the rays, or about even with the shallow interradial angles. Radii, 22 and 28^{mm}. The central dorsal oscule is well developed, surrounded with slender webbed, projecting spines in five groups of eight to ten each. The dorsal surface is covered with a multitude of crowded slender spinules, which project above the marsupial membrane and give almost the appearance of velvet pile, but in some places they form more or less evident divergent stellate clusters of twelve to twenty spinules. Seen from within these spinules are slender, 2 to 3^{mm} long, very divergent, supported by slender columnar paxillæ. The ambulacral grooves are broad and shallow. The ambulacral plates are somewhat bilobed at the inner ends and distally are somewhat imbricated. The adambulacral spines are long and slender, about five or six in a transverse row, of which the two inner ones are very small and slender, not half as long as the outer ones, of which there are three or four, about $3{\cdot}5^{mm}$ long. The appressed actino-marginal spines are distinctly longer and about twice as stout and blunt proximally, but distally, on the upturned part, where they are crowded, they become about equal in length to the adambulacrals and scarcely

Fig. 5.

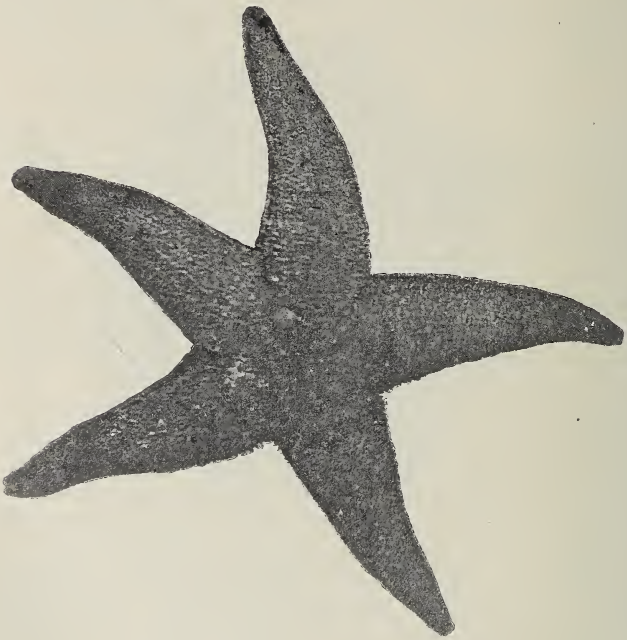

Fig. 5.—*Allasterias Rathbuni* V. Dorsal view ; ½ nat. size.

longer; those near the interradial angles are flattened and enlarged distally; the valves at the peractinal pores between their bases are very acute, small, and slender.

Departure Bay, Br. Columbia, 23 fathoms, mud and sand, 1908 (C. H. Young), Canada Geological Survey.

Hippasteria spinosa Ver., sp. nov.

Very similar in form and size to *H. phrygiana* of the N. Atlantic, but thickly covered with large, tapering, acute spines, usually one to nearly every dorsal plate and 1 to 3 on each marginal. Many of the plates also have large elevated bivalve pedicellariæ, but not so wide as in *phrygiana.*

Departure Bay, British Columbia, 18 fath. (H. C. Young), Canada Geol. Survey; Puget Sound (Prof. Kincaid).

Tosia arctica Ver., sp. nov. Figures 8, 8*a*.

Pentagonal with short obtuse rays. Disk thick; margins rounded. Radii 31 and 48^{mm}.

Dorsal plates, when granules are removed, are mostly elliptical or rounded, well spaced; granules are angular and coarse, and those of adjacent plates are in contact in alcoholic specimens, so that the plates mostly appear hexagonal or pentagonal; there are usually 6 to 8 marginal and one central granule on the larger plates; some have, also, a bivalve pedicellaria about equal to a granule in size. Marginal plates not very large, closely and coarsely granulated; the distal ones become less regular, partly rounded, and small. Plates of lower side uniformly coarsely granulated. Adambulacral plates have two short, thick furrow spines and five or six on outer part, often with a pedicellaria of similar size.

Bering Island (N. Grebnitsky, 1889). U. S. Nat. Mus. Type.

Asterias (*Pisaster**) *papulosa* Ver., sp. nov.

A very large 5-rayed species, with a high, swollen disk and long tapered rays. Radii of a medium-sized specimen, 42 and 210^{mm}; ratios, 1:5; rays, 45^{mm} broad at base, 43^{mm} high. A larger specimen is 660^{mm} broad.

The dorsal spines are few, short, thick, tapered, subacute; they form simple median radial rows; others are irregularly and

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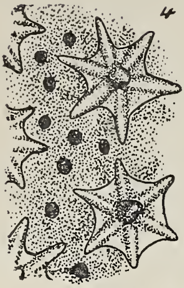
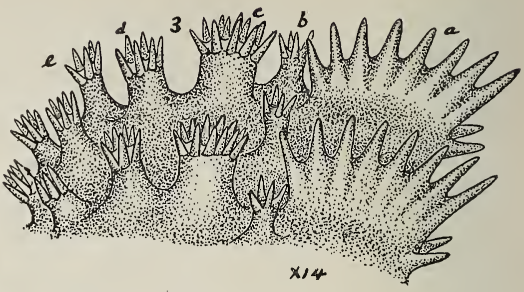
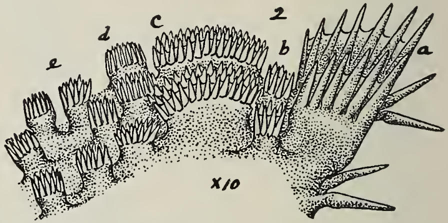
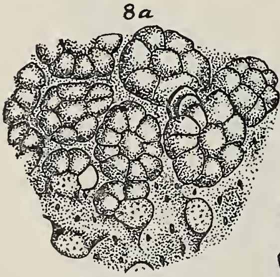
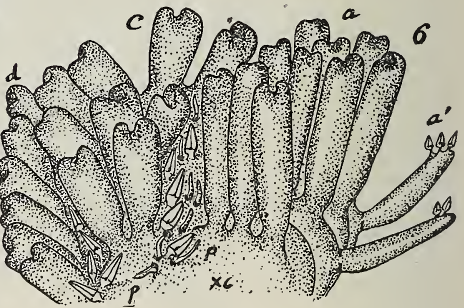
* This subgenus, or perhaps more correctly genus, first indicated by Müll. and Tr. (type *P. ochraceus*), has monacanthid adambulacral spines and remarkably large sessile denticulate pedicellariæ, and usually, in the adult, numerous rows of actinal plates and spines. *P. papulosus* is an exception, as to the last character. It includes, also, *P. fissispina*, *P. confertus*, *P. Lutkeni*, *P. capitatus*, *P. brevispina* and *P. giganteus*, all described by Stimpson from the N. P. coast.

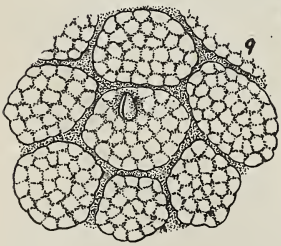


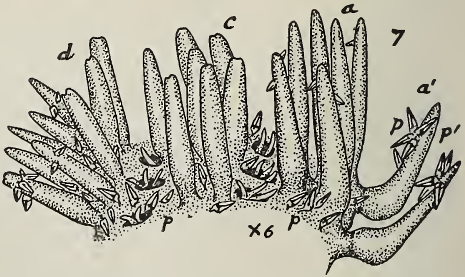












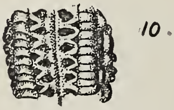


Fig. 2.—*Solaster galaxides* V. Profile view of adambulacral spines (*a*); peractinals (*b*); marginals (*c*, *d*); and abactinals (*e*); × about 14 times.

Fig. 3.—*Solaster constellatus* V. Lettering as above; × about 10.

Fig. 4.—The same; some of the abactinal pseudopaxillæ expanded, and papular pores; more enlarged.

Fig. 6.—*Allasterias Rathbuni* V., var. *anomala;* lettering as in fig. 2; *a'*, furrow spines; *p*, *p*, major pedicellariæ and papulæ. × about 6.

distantly scattered; distally somewhat in rows; also in ten small clusters around the disk. Papular areas very large, with very large dermal groups of minor pedicellariæ, and also large wreaths around the spines. Large wedge-shaped denticulate dermal major pedicellariæ are numerous. A simple upper row of marginal spines like the dorsals; infero-marginals much stouter, two to a plate; two regular simple rows of similar stout actinal spines, with many large denticulate pedicellariæ between them. Adambulacral spines long and slender in a very regular simple row. Large clusters of major pedicellariæ of various sizes, large and small, are attached within the ambulacral grooves. Vancouver I. (Prov. Mus., B. C.); British Columbia (Canada Geol. Survey), and Puget Sd. (Prof. Kincaid, type).

Allasterias Ver., gen. nov. Type *A. Rathbuni* Ver.

Remarkable for the arrangement of the adambulacral spines, in several series, of which one is deeper within the groove on alternate plates. Disk rather large, areolate. Dorsal ossicles numerous, but small, arranged, both on the disk and rays, in a reticulate manner around the papular areas, which are numerous, and bear large groups of small papulæ. Spines numerous, arranged irregularly, or placed around the papular areas, but usually forming a median radial series. Upper marginal plates rather large and stout, so as to form an angular margin, each bearing several spines larger than the dorsals. Lower marginals not close to the adambulacrals, bearing in the type two or three spines, longer than the upper ones. Actinals rudimentary or lacking.

Allasterias Rathbuni Ver., sp. nov. Figures 6, 7.

Rays five, broad at base and rapidly tapering to acute tips. Radii, 25 and 100^{mm}; ratios, 1 : 4. Small major pedicellariæ are abundant all over the dorsal and lateral surfaces.

The whole dorsal surface is conspicuously areolate or reticulate, the areolations mostly 1·5 to 2^{mm} broad. The dorsal spines are very small and numerous, sometimes almost like round or capitate granules, being scarcely higher than thick,

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Fig. 7.—The same, var. *nortonensis*; lettering as in fig. 6. × 6.

Fig. 8.—*Tosia arctica* V. Some of the dorsal interradial plates with granules removed; 8*a*, the same, some of the larger radial plates with granules and a pedicellaria; others bared of granules and showing papulæ; much enlarged.

Fig. 9.—*Tosia granularis*, dorsal radial plates, magnified the same as fig. 8*a*.

Fig. 10.—*Asterias* (*Leptasterias*) *macropora* V. Under side of ray of 5-rayed Alaska specimen, with spines removed, showing large size of ambulacral pores; × about 2.

but in other examples clavate or partly acute; they are arranged in single rows on all the ossicles, so as to form a border around the papular areas; toward the sides of the rays they are distinctly longer and mostly clavate or subacute.

The upper marginal spines form a wide band of small crowded spines, five to ten or more on a plate. They are larger and longer than the dorsals, and two or three times as long as thick, mostly cylindrical or clavate, sometimes gouge-shaped. Below this band there is a broad intermarginal channel with large papular areas and numerous rather large, pointed major pedicellariæ. This channel rapidly widens at the bases of the rays.

The lower marginals form a double row, mostly two to a plate; they are similar to the upper ones, but longer and mostly more clavate, often with gouge-shaped tips. Between the upper and lower marginals, at the bases of the rays, a short intermediate row of ossicles is sometimes interpolated.

Major or forficulate pedicellariæ are usually everywhere abundant, scattered over the surface, between the dorsal, marginal, and actinal spines, and especially on the lateral channels and interradial areas. The larger ones are compressed, rather large, lanceolate or acute-triangular, with a sharp or acuminate apex. Those that are scattered on the dorsal surface are much smaller, unequal in size, but similar in form, though less acute.

The type specimens are from Maloska (Prof. Kincaid). Specimens of varieties have also been sent from St. Michael's Island (L. M. Turner), 1873, No. 3821; Norton Sound (M. Murdoch), 1883, No. 7621, U. S. Nat. Mus. *A. amurensis* (Lutk.) is probably an allied species. Dedicated to Mr. Richard Rathbun of the National Museum.

Variety *anomala* V., nov. Figure 6.

This variety is remarkable for the very stout, crowded marginal and adambulacral spines, which are inflated distally and obtuse, with the tips excavate or gouge-shaped. (See fig.) Dorsal spines are small and capitate, but larger than in the type. Radii 23 and 87^{mm}. St. Michael's I. No. 3821, U. S. N. M.

Variety *nortonensis* V., nov. Figure 7.

This differs from the type in having the dorsal spines longer and more acute, and the infero-marginal and actinal spines longer and more tapered. Norton Sound (Murdock). No. 7621.

Asterias (*Urasterias*) *forcipulata* Ver., sp. nov.*

A very large species, allied to *U. Linckii.* Rays long and slender, gradually tapered; length of ray, 325^{mm}; breadth, 28^{mm}; disk small. Dorsal skeleton weak, with large papular areas nearly concealed by vast numbers of unusually large minor pedicellariæ.

The dorsal plates are small, three or five-lobed or stellate, each of the larger ones usually bearing a rather long tapered subacute spine; these are well spaced and form about five irregular or indefinite rows. The spines are surrounded by wreaths of the large minor pedicellariæ, but these also occur in larger clusters scattered over the integument between the spines. Large major pedicellariæ are also scattered over the back; these are stout, ovate-lanceolate, with obtuse tips, which are usually strongly denticulate.

On the sides of the ray and separated from those above by a wide papular band there is a row of small, mostly four-lobed marginals, usually bearing a single long spine. They are connected to those above and below by weak transverse bars, leaving large papular areas between. The spines are rather longer and larger than those of the dorsal surface. Between these and the adambulacral spines there is a single row of stouter spine-bearing plates, the infero-marginals; each corresponds to five or six adambulacrals. Most of these bear two long, tapered spines, usually blunt and somewhat flattened or sulcate at the tips, rather larger than the upper marginals, usually 7 to 8^{mm} long. Between their bases there are often scattered large and strong, denticulate, major pedicellariæ, similar to those of the back, but mostly stouter and more obtuse; with these are some that are much smaller, lanceolate, and subacute. The large pedicellariæ also occur on the naked spaces below, both on the papular areas and on the adambulacral plates. There are also some small synactinal ossicles connecting the peractinals with the adambulacrals, but not bearing spines. The adambulacral spines form two regular close rows, two on each plate; they are slender, tapered, mostly flattened, subacute, about 5 to 5·5^{mm} long. The ambulacral pores are large and form four rows.

The dorsal minor pedicellariæ are remarkable for their great size and abundance; in life they probably nearly conceal the whole upper surface and spines, and are borne on slender pedicels.

Departure Bay, Brit. Col., 18 fath., gravel (C. H. Young, 1908), Canada Geol. Survey.

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* The subgenus *Urasterias* is now proposed for this species, with *U. Linckii* and *U. panopla* Str. of the Arctic. It is characterized by the absence of spiniferous actinal plates, weakness of dorsal skeleton, great size and abundance of both kinds of pedicellariæ. Type *U. Linckii.*

Asterias polythela Ver., sp. nov.

Rays six, stout, of moderate length, rounded and with a firm skeleton. Radii 20 and 80^{mm}; ratios, 1 : 4.

Dorsal surface appears rough and rugged. It bears an irregular number of large, stout, round spines, arranged without order, except that in a few places two or three may stand in a median series; elsewhere they may be grouped, 2 to 5, near together, or stand singly. These spines stand on raised central bosses of the plates; they are constricted somewhat at base and then abruptly enlarged below the middle; the terminal part is regularly tapered or somewhat acorn-shaped or nipple-shaped, longitudinally finely grooved, ending in a blunt apex. They are 2 to 4^{mm} high and 1·5 to 2^{mm} in diameter. Scattered over the whole surface are many small, unequal, short, acorn-shaped and capitate spines, mostly from 2 to 4^{mm} in diameter. The large and small spines are all surrounded by close wreaths of small minor pedicellariæ; clusters of these are also attached to the skin, so that the surface appears to be almost covered with them.

The marginal and actinal rows of spines are pretty regular and smaller than the dorsals. The upper marginals stand mostly one to a plate proximally and two to a plate distally. They are shaped somewhat like the large dorsals and nearly as long, but only about half as thick. The lower marginals are about as long, but stouter; they stand either one or two to a plate. A short row of smaller spines is interpolated between the upper and lower marginals proximally. The peractinal spines are like the lower marginals proximally and form a regular row, one to a plate. The adambulacral spines are small, round, blunt, mostly two to a plate, sometimes one in certain parts, divergent and almost concealed by large clusters of small, ovate, major pedicellariæ on the inner ones, and clusters of major pedicellariæ on the outer ones; many large clusters of major pedicellariæ are attached to the inner edge of the plates within the furrow. A few much larger, blunt-ovate, major pedicellariæ with finely denticulate jaws, occur on the interradial spaces and between the proximal marginal spines.

The type was taken off the Arctic coast of Alaska by the U. S. R. S. "Corwin" in 1885, No. 16889 (U. S. Nat. Mus., No. 15820).

Asterias victoriana Verrill, sp. nov.

The type of this species is from near Victoria, British Columbia, sent by Mr. Newcombe. Radii, 20 and 95^{mm}; ratios, 1 : 4·75. Rays five, stout, rather rapidly tapered. Dorsal skeleton conspicuously reticulated, leaving large papular areas, which are mostly rounded or somewhat elliptical, the transverse diameter the greater. The intervening ossicles are strong and prominent above the surface, as narrow convex ridges; those at the intersections and in the radial rows larger and deeply four to six-lobed, convex in the middle, with a central mammilla and pit where the spine is attached.

The dorsal spines consist of two very unequal kinds. The larger ones are few in number and are widely scattered, except in the median radial line, where they form a pretty regular row; the others stand somewhat in quincunx, but may belong to about three imperfect rows on each side. These spines stand on the larger plates at the intersections of the reticulations. They are rather large, short, and thick, not much higher than broad, with enlarged, truncate or capitate tips, striated on the sides and rough on the top. They are about 1·5^{mm} broad. Between these there are many very small inconspicuous spines, arranged mostly in single rows along the narrow ossicles that form the sides of the reticulations. Some of them are acute, but most are slightly clavate with rough or spinulose tips. Both kinds are scattered irregularly on the central area of the disk.

Small minor pedicellariæ are thickly scattered over the whole surface between the spines and on the papular areas, and also form wreaths around the larger spines.

The supero-marginal spines form simple regular rows, and are much like the large dorsals in length and form, but are smaller. The intermarginal channel is well defined and of moderate width. The infero-marginal spines form a regular row, mostly simple, but frequently stand two on a plate distally. They are followed, proximally, by two pretty regular close parallel rows of actinal spines, of about the same size and shape. These three rows of ventral spines are longer than the supero-marginals and less clavate, but about as stout. They are blunt and sulcate at the tips. The first subactinal row extends only to about the end of the proximal third of the ray; on the proximal fourth there is also a simple row of synactinal spines.

The ossicles of the two marginal rows and next two actinals are thick, nearly equal in size and form, and proximally stand in four or five regular rows; the upper marginals are a little more removed, but the others are closely united in a tessellated manner, leaving only small papular pores between them. The exposed part is convex, with facets and pits for the spines. They are slightly four-lobed, but are so imbricated that they appear squarish with rounded corners, or ovate-triangular.

The synactinal ossicles are smaller, with an oblong or elliptical surface, and mostly bear a single spine; they extend only to about the proximal third of the rays.

The adambulacral spines stand two on a plate, or else in certain parts one and two alternately, thus forming two or three crowded rows. They are unequal, not very slender, the inner ones slightly tapered, the outer ones stouter, blunt, as long as the ventral spines, but more slender. They increase somewhat in length and thickness toward the mouth.

The two apical preoral spines are rather stouter and shorter than the adorals; their side spines are about half as long and more slender. The epioral spines are like the adorals.

The adoral carina is rather thick and stout, composed of three pairs of contingent plates beyond the epiorals, the third pair bearing two spines.

Major pedicellariæ of moderate size occur among the ventral spines and on the lateral and dorsal surfaces, but are not numerous.. They are compressed, lanceolate or acute-ovate, with sharp tips.

ART. X.—*On a Rare Rock Type from the Monteregian Hills, Canada;* by JOHN A. DRESSER.

[Published by permission of the Director of the Geological Survey of Canada.]

THE Monteregian Hills form a well-recognized petrographic province* consisting of eight hills composed of igneous rocks in the St. Lawrence valley extending along a line from Mount Royal at the city of Montreal eastward for a distance of fifty miles. They are a series of volcanic necks or laccoliths intrusive through Paleozoic sediments. The intrusions took place probably in Devonian times, since which there has been a long period of erosion succeeded by heavy glaciation, thus leaving hills of the butte type and composed of plutonic rocks. They are comparatively fresh and lend themselves particularly well to the method of determination required by the Quantitative Classification, which proves an invaluable aid in correlating them.

The rocks of these hills are those characteristic of alkalic magmas and the province may be compared to that of Essex county, Massachusetts, the Magnet Cove district, Arkansas, the Crazy mountains of Montana, in the United States of America, or to the Christiania district in southern Norway, or the Kola peninsula, Finland. In each of the hills there is a large development of essexite or theralite, and in all that have been studied in detail an alkali syenite, pulaskite, nordmarkite or nepheline syenite has been found. There is thus quite a wide range of composition between the different rocks of the individual hills. The mean composition of the hills compared one with another also varies considerably, but this variation is expressed in the different proportions of the essexite and syenite groups rather than by the occurrence of widely different rock types. The basic rocks are more extensively developed towards the western end of the group.

St. Bruno Mountain is the local name of the second of the Monteregian Hills from the western end. It is fourteen miles east of Montreal, near the line of the Grand Trunk Railway between Montreal and Portland or Quebec.

Many years ago a rock was noted from this hill by the late T. Sterry Hunt† to which he gave the name of "olivinitic dolerite or peridotite," and which is a somewhat different type from any of the series yet described. Hunt observed that olivine was the preponderating mineral in some portions of the

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* Adams, F. D., "The Monteregian Hills, a Canadian Petrographic Province," Journal of Geology, vol. xl, No. 3.

† Geology of Canada, 1863, p. 665 et seq.

rock. The writer in a recent examination, the results of which will be published in a report to the Geological Survey, did not find any part of the rock so rich in olivine as that, but found olivine commonly present up to 25 per cent, as well as could be judged by the eye. The rock is dark greenish black or brown in color. Pyroxene, olivine, biotite, sometimes feldspar and usually specks of pyrrhotite can be distinguished in it by the unaided eye. It is an even-grained, plutonic rock having a rather coarse texture.

In the thin section it is found to be composed essentially of pyroxene, olivine, brown hornblende, biotite, and labradorite. The hornblende and biotite are often intergrown with each other and sometimes with the pyroxene. The accessory minerals, pyrrhotite, titanite and apatite, are in their characteristic positions with the earlier constituents. The general order of crystallization has, therefore, been—olivine and accessories; pyroxene; hornblende and biotite; feldspar. A fresh specimen, which did not represent the maximum content of olivine seen, was taken and submitted for analysis to Mr. M. F. Connor of the Geological Survey, Ottawa, Canada, who gives the following results in column I:

	I*		II	III	IV
SiO_2 -----	45·37		39·97	48·63	49·02
Al_2O_3 ----	6·21		8·68	5·32	10·14
Fe_2O_3 ----	2·40		8·63	2·91	1·54
FeO -----	8·09		7·99	3 90	10·46
MnO -----	·15		·19	·12	0·16
NiO + CoO	·17	$P_2O_5 + FeS_2$	1·11	·21	0·11
MgO -----	18·67		10·32	21·71	17·25
CaO -----	14·47		15·18	13·04	8·29
NaO -----	·85		1·19	·34	1·59
K_2O -----	·37		·74	·23	0·40
CO_2 ------	·62		1·15	----	----
TiO_2 -----	1·50		4·05	·47	0·99
H_2O -----	·88		·57	2·81	0·75
	99·75		99·89	100·13	100·70

* I Palisadose, St. Bruno Mt., Quebec, M. F. Connor, analyst. II Yamaskose (yamaskite) Mt. Yamaska, Quebec, G. A. Young, analyst. III Belcherose, Belchertown, Mass., L. G. Eakins, analyst. IV Palisadose (olivine diabase) Englewood Cliffs, N. J., R. B. Gage, analyst.

Calculating the molecular ratios in Analysis I and reducing these to percentages of standard minerals, the norm is found to agree so closely with the estimated mineralogical composition of the rock that it may be safely considered a normative rock.

	Norm		
Anorthite	12·23		
Albite	2·88		
Nepheline	2·13		
Orthoclase	2·22,	total salic	19·46
Diopside	47·24		
Olivine	25·05		
Magnetite	3·48		
Ilmenite	2·89,	total femic	78·66
	CO_2, calcite being secondary		·62
		H_2O	·88
			99·62

The rock thus falls in—

Class IV		Dofemane
Order I		Hungarare
Section 2	(name proposed)	Quebeciare
Rang 1	" "	Quebecase
Section 2	" "	Bruniase
Subrang 2		Palisadose

The new names used above are proposed on the advice of Professor J. P. Iddings and Dr. F. D. Adams, to both of whom the writer is indebted for advice in the matter.

A rock of closely similar composition has recently been described by Professor J. Volney Lewis[*] from the Palisades of the Hudson. This is a highly olivinitic facies of the diabase of that well-known locality. An analysis of it is given in column IV. From it the name Palisadose has been given to the subrang of the Quantitative Classification, of which it was the first representative rock described.

As the rock from St. Bruno is a distinct phase of the well-defined petrographic province of the Monteregian hills in which allied varieties are likely to be found, it has been thought that the larger divisions of the Quantitative Classification might be suitably named as above proposed.

The nearest related rock in the Monteregian series, that has thus far been described, is that named Yamaskite by Dr. G. A. Young from Yamaska Mountain[†] in which it occurs. The analysis of this rock is given in column II, while in column III is given an analysis of Belcherose from Belchertown, Mass., described by Professor B. K. Emerson (U. S. G. S. Monograph XXIX, p. 347, 1898).

McGill University, Montreal, Canada.

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[*] Annual Report of the State Geologist of New Jersey for 1907, p. 124.

[†] Report Geological Survey, Canada, vol. xvi.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Cuprous Sulphate.*—A. Recoura has succeeded in preparing this hitherto unknown salt, Cu_2SO_4. Two complex compounds of the salt, $Cu_2SO_4.2CO.H_2O$ and $Cu_2SO_4.4NH_3$ had been prepared previously, but when attempts were made to remove the carbon monoxide or the ammonia from these compounds, the cuprous sulphate was decomposed at the same time. The reason for previous failures to prepare cuprous sulphate lies in the fact that the compound is instantly decomposed by water, and it has at last been prepared by the action of an anhydrous reagent, methyl sulphate, upon cuprous oxide. The reaction produces gaseous methyl ether as indicated by the equation $Cu_2O+(CH_3)_2SO_4=Cu_2SO_4+(CH_3)_2O$. The reaction can be carried out with great ease by heating finely pulverized cuprous oxide with a large excess of methyl sulphate in a flask to 160° C. No precautions for the exclusion of air are necessary, but the heating should be stopped as soon as the evolution of gas has ceased, for otherwise a second reaction sets in whereby the product is changed to cupric sulphate by the action of the methyl sulphate. The product is a grayish white powder which is perfectly stable in dry air. It is only slowly attacked by moist air under ordinary conditions, but when it is wet with ether and the ether is allowed to evaporate in the air, it is oxidized with great rapidity, in a peculiar way, forming a mass as black as soot. This black oxidation product when treated with water appears to yield the black oxide Cu_4O, which has been described by Rose, and cupric sulphate. The unoxidized salt gives with water cupric sulphate and metallic copper, a reaction which yields a disengagement of heat amounting to 21 calories. This thermochemical relation is opposite to that existing between cuprous and cupric oxides, chlorides and sulphides, where the cuprous compounds are formed exothermically.—*Comptes Rendus*, cxlviii, 1105. H. L. W.

2. *The Action of Hydrogen Antimonide upon Dilute Silver Solutions.*—The familiar precipitate formed when hydrogen antimonide is passed into a silver solution is usually regarded as Ag_3Sb, formed according to the equation $H_3Sb+3AgNO_3=Ag_3Sb+3HNO_3$. A number of investigators, however, have been led to the conclusion that the reaction is more complicated than the one represented by this equation. H. Reckleben has recently made a careful study of this reaction, and has found that in the first place silver antimonide, Ag_3Sb, is formed according to the above equation, but that this precipitate then reacts to a considerable extent with the excess of silver nitrate as follows:

$$Ag_3Sb+3AgNO_3+3H_2O=6Ag+H_3SbO_3+3HNO_3.$$

We have, therefore, as the final product a mixture of metallic silver with much H_3SbO_3 and little metallic antimony, while an appreciable quantity of the antimonious acid goes into solution. The reaction is precisely similar to that of hydrogen arsenide with silver solutions, except that in the latter case the arsenious acid, being more soluble, goes into solution.—*Berichte*, xlii, 1458.

H. L. W.

3. *The Separation of Antimony and Tin.*—G. PANOJOTOW has devised a simple and rapid method for the separation of these metals, which can be used in all cases where the antimony is in solution in the trivalent condition. To the solution is added enough concentrated hydrochloric acid to give about 15 per cent of the actual acid, then it is heated to 50–60° C. and a rapid stream of hydrogen sulphide is passed in for 30 minutes. A yellow precipitate appears at first, but soon the cinnabar-red, anhydrous antimony sulphide is formed, which settles rapidly. The liquid is then cooled below 30° C., and a very moderate stream of hydrogen sulphide is passed in for 10 minutes. Then the precipitate is quickly filtered upon a Gooch crucible, washed with 15 per cent hydrochloric acid which has been saturated with hydrogen sulphide until the tin has been removed, then the hydrochloric acid is removed by washing with strong hydrogen sulphide water. After this the antimonious sulphide is washed successively with alcohol, a mixture of alcohol and carbon disulphide, alcohol, and ether. It is then dried at 110° and weighed. The tin in the filtrate is precipitated with hydrogen sulphide after partially neutralizing with ammonia, diluting with water, and heating. Test analyses gave excellent results with widely varying quantities of the two metals.—*Berichte*, xlii, 1296.

H. L. W.

4. *The Purification of Sulphuric Acid by Freezing.*—It is well known that sulphuric acid containing about 94 per cent of the "monohydrate," H_2SO_4, yields crystals of the 100 per cent acid upon cooling to about −20° C., and upon this fact is based a method of concentrating such acid upon a commercial scale. MORANCÉ has found that a considerably weaker acid, if of just the proper strength, will crystallize at a few degrees below zero, and will yield a stronger and purer product than the original material. In a case where an impure acid had been frozen so that almost exactly equal weights of solid and liquid were produced, he obtained the following results upon analyzing the products:

	Crystals	Mother liquor
Ignited residue	0·2320	0·5730
Iron and alumina	0·0241	0·0825
Arsenic	0·0275	0·2250
Sulphuric acid	82·45	69·1

The results show a particularly good purification from arsenic by the crystallization.—*Comptes Rendus*, cxlviii, 842.

H. L. W.

5. *Heat of Formation and Stability of Lead and Silver Compounds.*—The impossibility of predicting from thermochemical data the relative stability of similar compounds of lead and silver has been shown by **Albert Colson**. It might be supposed that the carbonate and nitrate of lead would be more stable than the corresponding silver salts from the following heats of formation :

For $PbCO_3$	166600	cal.
For Ag_2CO_3	120800	"
Difference	45800	"

For $Pb(NO_3)_2$	105400	cal.
For $Ag_2(NO_3)_2$	57400	"
Difference	48000	"

Now while lead carbonate shows the expected greater stability, as it was found to give a vapor tension of one atmosphere at 285° in comparison with 220° for silver carbonate, the nitrates show an opposite relative stability, as lead nitrate gave off red vapors at 283° while silver nitrate was not decomposed even at 350° in a vacuum. The author has previously shown also that in the general reactions of organic substances the results are not necessarily governed by the maximum of disengaged heat.—*Comptes Rendus*, cxlviii, 837. H. L. W.

6. *Refraction of Röntgen Rays.*—W. Wien and I. Stark independently have shown that by the application of Planck's radiation theory to Röntgen rays one obtains wave lengths which agree closely with the values $5–16.10^{-9}$ cm. obtained by Haga and Wind. In view of this **B. Walter** and **R. Pohl** have renewed their work upon the subject of the refraction of the rays, and do not find any evidence of this refraction. If this does occur the wave lengths must be less than $1{\cdot}2.10^{-9}$ cm. ; a suitably small bundle of the rays through a slit 2μ wide at a distance of 80 cm. affords no evidence of refraction. Planck's wave length deduced from the quantity of energy theory is at the lowest $4{\cdot}5.10^{-9}$ cm. The authors conclude, therefore, that there is a discrepancy between this theory and their observations, still to be investigated.—*Ann. der Physik*, No. 7, pp. 331–354. J. T.

7. *Polarization of Röntgen Rays.*—In an investigation upon this subject Haga has stated that the secondary rays are polarized by a plate of carbon, and that these rays also are slightly polarized by copper, aluminium and lead. He could not, however, obtain any trace of polarization from the primary Röntgen rays. J. **Herweg** is led to examine the primary rays proceeding from an anti-cathode of carbon, and obtains evidence, in this case, of polarization. He concludes that the rays from carbon differ in a marked degree from those coming from metals.—*Ann. der Physik*, No. 7, pp. 398–400. J. T.

8. *The Absorption of the γ-Rays of Radium by Lead.*—Various observers have studied this subject, and have obtained exponen-

tial expressions for the absorption with increasing thickness of lead. Y. TAOMIKOSKI has used greater thicknesses of lead than Rutherford, McClelland, Wigger and Eve. He finds that the radiation after passing through a noticeable thickness of lead does not diminish exponentially with increasing thickness of lead.—*Physik. Zeitschrift*, June 1, 1909, pp. 372–374. J. T.

9. *Use of Zinc Sulphate in the Braun Tube.*—The Braun tube is of great use in the study of alternating currents and an increase in the spot of light produced by the moving beam of cathode rays on the fluorescent screen is very desirable from the photographic point of view. F. GIESEL and J. ZENNECK describe the use of zinc sulphide, and show by photographs the advantages of its employment.—*Physik. Zeitschrift,* June 1, 1909, pp. 377–379. J. T.

10. *Die Luftelektrizität. Methoden und Resultate der neueren Forschung;* von Dr. ALBERT GOCKEL. Pp. vi, 206. Leipzig, 1908 (S. Hirzel).—The problem of atmospheric electricity entered a new phase with the discovery of the ionization of gases by Röntgen- and Becquerel-rays and with Wilson's observation that gaseous ions may act as nuclei for the condensation of water-drops. A great amount of work has been done in the last ten or twelve years, especially by Elster and Geitel and their followers, which will, doubtless, prove to be of great importance to scientific meteorology. Dr. Gockel has done much work of this kind, and in the present volume he gives a most useful résumé of the methods and results of the modern investigations of this complex and difficult subject. H. A. B.

11. *La Materia Radiante e i Raggi Magnetici;* by AUGUSTO RIGHI. Pp. vi, 308. Bologna, 1909 (Nicola Zanichella).—This volume (No. 12 of the series "Attualità Scientifiche") begins with brief account of cathode, anode, canal and Becquerel rays. The greater part of the book is devoted to the so-called "Magnetic rays" to which attention has recently been directed, particularly by Villard. Professor Righi proposes the hypothesis that these rays are streams of neutral pairs consisting of a positive ion and a negative electron, rotating about each other. He has made many ingenious experiments which are here described, and which appear on the whole to lend support to his hypothesis. There is a mathematical appendix in which the theory of the motion of such systems is discussed. H. A. B.

12. *A Text-book of Sound;* by EDWIN H. BARTON. Pp. xvi, 687. London, 1908 (Macmillan & Co.).—The author has assumed on the part of the student no previous knowledge of sound and, in mathematics, only a knowledge of the elements of the calculus. Nevertheless a student who reads this book will have an extensive and satisfactory knowledge of all the essentials of the subject. The dynamics of vibrating bodies and of wave motion are neither shirked nor neglected, although (very properly) the more intricate and complicated special cases are omitted. The experimental side of the subject is well and fully treated and in

general the book is an excellent example of what a text-book on a physical subject for the use of serious students should be.

H. A. B.

13. *Applied Mechanics for Engineers;* by E. L. HANCOCK. Pp. xi, 385. New York, 1909 (The Macmillan Co.).—The author's main purpose, as stated in his preface, is to emphasize the applications of mechanical theory to practical engineering problems. This design appears to have been successfully carried out; the numerous problems given are good examples of mechanical principles and are at the same time stated in terms of angle-irons, fly wheels, governors, and other concrete mechanisms. On the other hand the physicist or mathematician will find much to complain of in the loose and often inaccurate definitions and statements of fundamental laws and principles. It would seem that even for students of engineering a little more attention to logical relations might be of value. H. A. B.

14. *The Absorption Spectra of Solutions;* by HARRY C. JONES and JOHN A. ANDERSON. Pp. 110 with 81 plates. Publication No. 110, Carnegie Institution of Washington, 1909.—This investigation is a continuation of the work of Jones and Uhler which was begun in 1905 (see Carnegie Publication No. 60). The amount of work performed by the authors is so great as to preclude the possibility of doing it justice in this brief review. Nevertheless the following salient points are especially worthy of notice.

The absorption spectra of solutions, in various solvents, of twenty-four colored salts were photographed from λ 2000 to λ 7400 and studied in detail. Some idea of the scope and thoroughness of the investigation may be formed from the fact that about 1200 solutions were studied and that 1138 photographic strips, each corresponding to a different solution, are reproduced in eighty excellent, full-page plates. In general, the authors have been able to draw definite conclusions as to whether a given absorption band is due to ions, or to atoms, or to undissociated molecules, and also as to the existence and relative importance of solvates. Undoubtedly the most interesting and valuable results were obtained in connection with the spectra of the three rare earths investigated and especially in the case of neodymium chloride. When this salt was dissolved in mixtures of varying proportions of water and methyl alcohol it was found that the apparent shifts in the bands were not real, as has usually been believed heretofore, but that the effect observed is the result of the superposition of two distinct sets of absorption bands, the one set being identical with that exhibited by solutions in pure water and the other by solutions in anhydrous methyl alcohol. Ethyl alcohol and water gave similar results.

In conclusion, attention should be called to the source of ultraviolet light used by Jones and Anderson, which is a marked improvement over anything employed in the past. Taken as a whole, Publication No. 110 is a valuable contribution to the subject of solutions and absorption spectra. H. S. U.

15. *Electricity, Sound and Light;* by R. A. Millikan and J. Mills. Pp. 389. Boston and New York, 1908 (Ginn & Co.).—"This book represents primarily an attempt to secure a satisfactory articulation of the laboratory and class-room phases of instruction in physics." "It is designed to occupy a half-year of daily work, two hours per day, in either the freshman, sophomore, or junior years of the college or technical-school course." This text-book supplements the course contemplated in Millikan's "Mechanics, Molecular Physics and Heat."

The authors have designed (and tested) the entire course in such a wholesome, common-sense way that we are of the opinion that an instructor who adopts their text-books and follows their plans will approximate more closely to ideal conditions of teaching-efficiency than can be attained by the customary scheme of independent class-room and laboratory courses. H. S. U.

16. *Einführung in die Elektrotechnik;* by C. Heinke. Pp. xix, 501; with 512 figures. Leipzig, 1909 (S. Hirzel).—This text embodies, in an attractive and useful form, the author's course of lectures in the Munich Technical School; it is designed as a connecting link between abstract electrophysics and the technical applications of electricity. The subject matter is treated under the following seven captions: Introduction; mechanical analogies helpful in comprehending the fundamental phenomena of electromagnetism; the generation of potential difference; the technical generation of electrical energy; the utilization of electrical power by its transformation into other forms of energy; electrical measuring instruments; leads and accessory apparatus. The discussions are direct and clear; the illustrations and mechanical features, without exception, excellent. Topics of the articles are printed on the margin of the page, but there is no index. D. A. K.

17. *La Machine à Influence, son Évolution, sa Théorie;* by V. Schaffers. Pp. vii, 506; with 197 figures. Paris, 1908 (Gauthier-Villars).—The purpose of this book, as stated by the author, is to assemble, coördinate and perfect, so far as possible, all of value that has been published on influence machines. A more comprehensive and detailed description is given, of all of the important influence machines, as well as of electrostatic motors, than is to be found in any previous compilation; and a serious attempt is made to cover the theory of each part. The author has made a number of original contributions to the subject. His hydraulic models are of some interest; but of doubtful value in elucidating the principles of the machines. The results of a large number of quantitative measurements are given, showing the quantity of electricity produced per second, the potential difference maintained and the efficiency of the several types of machines under varying conditions of atmosphere and manipulation. In all probability the influence machine has attained, in design if not in theory, its final stage of development; in view

of which fact this rather thorough compilation will prove of permanent value. It is much to be regretted that books of this type continue to be published without an index. D. A. K.

II. Geology and Natural History.

1. *Publications of the United States Geological Survey*, George Otis Smith, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from p. 406, vol. xxvii):

Topographic Atlas. Twenty-eight sheets.

Folios.—No. 164. Belle Fourche Folio, South Dakota. Description of the Belle Fourche Quadrangle; by N. H. Darton and C. C. O'Harra. Pp. 9, columnar section, 4 maps.

No. 165. Aberdeen-Redfield Folio, South Dakota. Northville, Aberdeen, Redfield and Byron Quadrangles. Description of Aberdeen-Redfield District; by J. E. Todd. Pp. 13, 12 maps.

Bulletins.—No. 373. The Smokeless Combustion of Coal in Boiler Plants with a chapter on Central Heating Plants; by D. T. Randall and H. W. Weeks. Pp. 188, 40 figures.

No. 374. Mineral Resources of the Kotsina-Chitina Region, Alaska; by F. H. Moffit and A. G. Maddren. Pp. 103, 10 plates, 9 figures.

Water-Supply Papers.—No. 223. Underground Waters of Southern Maine; by Frederick G. Clapp, with records of deep wells by W. S. Bayley. Pp. 268, 24 plates, 4 figures.

No. 229. The Disinfection of Sewage and Sewage Filter Effluents, with a chapter on the Putrescibility and Stability of Sewage Effluents: by Earle Bernard Phelps. Pp. 91, 1 plate.

No. 230. Surface Water Supply of Nebraska; by J. C. Stevens. Pp. 251, 6 plates, 5 figures.

No. 231. Geology and Water Resources of the Harvey Basin Region, Oregon; by Gerald A. Waring. Pp. 93, 5 plates.

Also advance chapters from Bulletin No. 380. Contributions to Economic Geology, 1908, Part I.

2. *Geological Survey of Canada*, R. W. Brock, Director. Department of Mines, Geological Survey Branch. Ottawa, 1909.—The following publications have been recently received.

Summary Report of the Director for the Calendar Year 1908. Pp. 220. This report contains a concise statement of the operations of the Survey for 1908. Some of the subjects discussed are the following: The investigation of coal fields in the Yukon; of copper and gold deposits on Texada island; of the geology of the southeastern part of Vancouver island; investigation of the Gowganda district in northern Ontario, which is a promising silver camp, having some features in common with the celebrated Cobalt region (see below). E. R. Fairbault notes that the valuable calcium tungstate, scheelite, occurs somewhat abundantly at a number of localities in the Moose river gold district, Halifax county, N. S.

Annual Report on the Mineral Production of Canada during the Calendar Year 1906. Pp. 182.

Preliminary Report on Gowganda Mining Division, District of Nipissing, Ontario; by W. H. COLLINS. Pp. 47, 7 figures and map in separate envelope.

Report on Tertiary Plants of British Columbia, collected by LAWRENCE M. LAMBE in 1906, together with a Discussion of Previously recorded Tertiary Floras; by D. P. PENHALLOW. 4to, pp. 167, 32 figures.

Contributions to Canadian Palæontology, Volume III, Part IV. The Vertebrata of the Oligocene of the Cypress Hills, Saskatchewan; by LAWRENCE M. LAMBE. 4to, pp. 64, 8 plates.

Two Geological maps of Hastings, Haliburton and Peterborough counties; by F. D. ADAMS and A. E. BARLOW. Shuswap Sheet, British Columbia, 2 maps, G. M. DAWSON and J. MCEVOY; map of southwest coast of Hudson Bay.

3. *Geological Survey of Western Australia.* Bulletin No. 32, pp. 91, with 3 maps and 7 plates; by HARRY P. WOODWARD, Assistant Government Geologist. Perth, 1908.—This recent publication contains an account of the Greenbushes Tinfield; of the Mt. Malcolm copper mine, Eulaminna; of Fraser's gold mine, Yilgarn gold field. The primary tin deposits occur in crystalline granite rocks, which lie within a belt of greenstone and greenstone schists; there are also secondary alluvial deposits. The amount mined in 1906 was 783 tons and in 1907, 770 tons. Various rare minerals occur with the tin ore, including tantalite, stibiotantalite, microlite, gahnite, etc. It is noted, also, that particles of undoubted *metallic tin* have been found, but it is suggested that they may owe their origin to the action of bush fires on surface exposures of tin ore.

4. *New Zealand Geological Survey Department. Second Annual Report* (*New Series*), Wellington, 1908. Pp. 39, 8 plates, 2 maps.—This report gives a concise summary of the operations of the New Zealand Geological Survey between January 1, 1907, and May 31, 1908. It deals in part with the topography, in part with the geology, including the economic side. An interesting account is given of the survey of the Franz Josef and Blumenthal glaciers. The accompanying maps exhibit the portions of the islands which have thus far been accurately surveyed.

5. *Report of the Mineral Survey of Ceylon,* JAMES PARSONS, Principal Mineral Surveyor.—In addition to the general statement in regard to the mineral production of Ceylon, this report notes the discovery of a new locality of moonstone at Weragoda in the Southern Province. Thus far practically the entire world supply of moonstone has been obtained from the rock leptynite in the Kandy district in Ceylon. At the new locality the moonstone is obtained by sinking pits in the swamp through some 4½ feet of black mud, when a white kaolin is obtained, which, on being washed, yields the gems. It is probable that here, as in the Kandy district, it is derived from a similar rock *in situ*, but this

is so much decomposed that the material can only be dug out and washed.

In regard to the thorianite, the discovery of which excited much interest some few years since, it is noted that the original deposits in the alluvium have been practically exhausted. The mineral evidently occurs in segregations in the pegmatite, which, in decomposed condition, has been mined to some extent but not thus far with important results. The quantity exported in 1907 was 10 cwt. valued at 4,750 rupees. It may be noted, also, that the amount of mica exported from Ceylon in 1907 was 426 cwt., valued at 15,000 rs.; of graphite the amount was 650,000 cwt., valued at nearly 9,000,000 rs. The report closes with a list of the mineral species known to occur in Ceylon.

6. *Mineral Resources of Virginia;* by THOMAS LEONARD WATSON, Ph.D. Pp. xxxi, 618, with 83 plates and 101 figures. Lynchburg, Va., 1907 (J. P. Bell Co.). The Virginia-Jamestown Exposition Commission.—This volume was planned in connection with the Virginia-Jamestown Exposition, to call attention to the remarkable resources of the state in its mineral wealth. The state of Virginia has an unusually favorable position as regards mineral resources, not only with respect to their diversity and extent, but also the satisfactory conditions for work, due to the mild climate and cheapness of labor, There has been a very rapid development in this direction within the past few years, the production having increased three-fold from 1902 to 1906 ; in the last-named year the total valuation of production having been $30,000,000. Professor Watson is well equipped for the work he has done here, and in preparing this volume he has made use of the extensive material available on the subject from the reports of Prof. Rogers in 1835 down to the publications of the present time. He has also been aided by contributions from Dr. R. S. Bassler on cement and cement materials, by Prof. H. Ries on clays, and by Prof. R. J. Holden on iron. The volume opens with a brief statement of the general geology of the state, with various columnar sections; this forms Part I. Part II (pp. 16–187) is devoted to the building and ornamental stones, cement, and clays ; Part III (pp. 188–401) to non-metallic minerals, including pyrite, manganese oxides, mica, barite and gypsum, coal, etc. ; while the closing part (pp. 402–582) discusses in detail the ores of iron, copper, zinc and lead, gold and silver. The volume is illustrated by numerous plates and maps, and cannot fail to accomplish the object for which it was written.

7. *Minerals of Arizona: their Occurrence and Association, with Notes on their Composition ;* Report to the Hon. J. H. Kibbey, Governor of Arizona, by WILLIAM P. BLAKE, Territorial Geologist. Pp. 64. Tucson, 1909.—Arizona has been so rich in its mineral production that this concise account by Prof. Blake of the species thus far discovered will be found most convenient for reference by all mineralogists. It is noted that in 1908 the copper production reached the large amount of 252,785,000 lbs.

8. *Das Salz, dessen Vorkommen und Verwertung in Sämtlichen Staaten der Erde; verfasst von* J. Ottokar Freiherrn Buschman. I Band. Europa. Pp. xiv, 768. Herausgegeben mit Unterstützung der K. Akademie der Wissenschaften in Wien aus der Treitl-Stiftung. Leipzig, 1909 (W. Engelmann).—The second volume of this exhaustive work on Salt was published two years since (see volume xxiii, p. 153), and was devoted to the various countries in the world outside of Europe. The present ponderous volume of nearly 800 large octavo pages is given to Europe, and presents the facts with the same degree of thoroughness and minuteness. The work is divided geographically according to countries, beginning with Russia, after which follow Germany, Austria-Hungary, Great Britain, France, Italy, etc. In each case the same general heads are adopted, under which the multitude of facts presented are arranged, viz.: The occurrence and exploitation of salt; the amount of import and export; the salt trade and the use of salt. Numerous references to the literature open each division of the work, and many explanatory foot-notes accompany the text, adding to the completeness of the work as a whole.

9. *Brief Notices of some Recently Described Minerals.*—**Delorenzite** is a titanate of yttrium, uranyl, tin and iron, perhaps related to polycrase. It is described by Zambonini as occurring in the pegmatite of Craveggia in Piedmont, sometimes associated with strüverite. Its crystallization is orthorhombic, the crystals being slender, of prismatic habit; hardness 5·5–6; specific gravity 4·7; luster resinous; color black, in thin splinters chestnut-brown. An analysis by Sterba gave:

TiO_2 66·03 SnO_2 4·33 UO_2 9·87 Y_2O_3 14·63 FeO 4·25 = 99·11

From the above the formula $2FeO.UO_2.2Y_2O_3.24TiO_2$ is calculated.—*Zeitschr. Kryst.*, xlv, 76, 1908.

Georgiadésite is a chloro-arsenate of lead, described by Gaubert as occurring with other secondary lead minerals at the ancient mines of Laurion, Greece. Crystallization orthorhombic, crystals small, of short prismatic habit and hexagonal in aspect, with $m(110)$, $b(010)$, $e(011)$, angle $bm = 60°1'$; hardness 3·5; specific gravity 7·1; luster resinous; color white to brownish-yellow. An analysis gave:

As_2O_5 12·49 PbO 38·86 Pb 36·38 Cl 12·47 = 100·20.

This is interpreted as $Pb_3(AsO_4)_2.3PCl_2$, which brings it near mimetite. Named after M. Georgiadés, Director of mines at Laurion.—*Bull. Soc. Min.*, xxxi, 86, 1908.

Taramellite is a silicate of iron and barium, described by E. Tacconi from the granular crystalline limestone of Candoglia, Valle del Toce, Italy. It forms columnar or radiated fibrous aggregates of a brownish-red color; hardness 5·5; specific gravity 3·92. An analysis gave:

SiO_2 36·56 Fe_2O_3 21·54 FeO 4·47 BaO 37·32 = 99·89.

The formula deduced is $4BaO.FeO.2Fe_2O_3.10SiO_2$. The mineral is named for Prof. T. Taramelli.—*Centralbl. Min.*, 506, 1908.

TARBUTTITE is a basic zinc phosphate from the Broken Hill mines in Rhodesia, described by L. J. Spencer. It occurs in aggregates of small triclinic crystals, often forming an incrustation on limonite. The crystals vary from colorless to pale shades of yellow, brown, red or green; luster vitreous, but pearly on the surface of perfect cleavage; hardness 3·75; specific gravity 4·12. An analysis gave:

$$P_2O_5\ 29{\cdot}2 \quad ZnO\ 66{\cdot}6 \quad H_2O\ 3{\cdot}8 = 99{\cdot}6.$$

The formula obtained is $Zn_3(PO_4)_2.Zn(OH)_2$. The mineral is named for P. C. Tarbutt, who collected the specimens.

PARAHOPEITE is from the same locality as tarbuttite; and is also described by L. J. Spencer. It has the chemical composition of hopeite, but differs in physical and crystallographic characters. It is triclinic, and is a little higher than hopeite in hardness (3·75) and specific gravity (3·31). The same author gives an exhaustive account of hopeite, distinguishing two varieties, α-hopeite and β-hopeite.—*Min. Mag*, vol. xv, pp. 1, *et seq.*

RINNEITE is a chloride of iron, potassium and sodium, having the formula $FeCl_2.3KCl.NaCl$. It is described by H. E. Boeke as occurring in coarse granular aggregates at the potash-salt works in the southern Harz. It is soluble in water, having a strong astringent ink-like taste; hardness 3; specific gravity 2·34. The mineral is named after Geheimrat Rinne-Kiel.—*Centralbl. Min.*, 72, 1909.

10. *Guide dans la Collection des Météorites avec le Catalogue des Chutes représentées au Muséum.* (Édition A. LABAT.) Pp. iv, 58. Muséum Nationale D'Histoire Naturelle, M. STANISLAS MEUNIER, Professeur. Paris, 1909 (Laboratoire de Géologie du Muséum).—The Museum of Natural History at Paris has, for many years, possessed one of the great collections of meteorites of the world. A considerable period has now passed since the last catalogue was issued, and the present one, edited by Dr. Labat, gives a total of 532 occurrences. The pages preceding the catalogue proper are devoted to general subjects, including the presentation of the well-known system of classification advanced by Meunier. He recognizes 67 classes named from the typical localities; 28 of these fall among the irons, or siderites; 10 to the lithosiderites, and the remainder to the stones, or lithites.

11. *Mendel's Principles of Heredity;* by W. BATESON, F.R.S., Professor of Biology in the University of Cambridge. Cambridge, England, 1909 (The University Press).—In the June number of this Journal (p. 491), the present writer called attention to this important treatise, and promised to notice further, in a subsequent issue, the special contribution by Professor Bateson. As is well known, this investigator has given much attention to the general subject of heredity, and has the distinction of having been one of the earliest defenders of Mendel's methods and views. The defence was on the whole well conducted, but in the course

of it certain positions were taken which were later shown to be untenable. From these positions, Professor Bateson has retreated gracefully. In the present treatise he has endeavored to present some of the more important facts relative to the study of certain types, and this necessarily involves much condensation. It is just here that the work strikes us as excellent in all respects. To select from the rapidly accumulating stores of facts those which are most telling, and to set these forth in a short yet clear manner, is a task of great difficulty. It must not be expected by the casual reader that a work on a topic so vast and recondite as this will prove easy reading; it is not: but it is straightforward and free from unnecessary complications. Professor Bateson has here given some of the more interesting as well as important studies in animals and plants, and has devoted a considerable part of his space to color and color-ratios. It is this which will open up to young naturalists an absorbingly attractive field for original investigation. When one recalls the admirable work which has been done by amateurs in the study of the relations of flowers to insects, it is not difficult to believe that this neighboring field may receive assiduous cultivation at their hands. To such, as well as to professional biologists, Professor Bateson's work will serve as an admirable guide, safe in all respects. There is only one word of caution to those entering this field of study: be as sure as you can that you know the source of the material which you have under investigation. Do not forget—what is too often forgotten—the difference between a species and a race, and do not confound species-hybrids with the crosses between races and between varieties. We do not mean, of course, that we can as yet distinguish in all cases between species and races, but we can at least choose as material those plants about which there is comparatively little question. In these days, when some of our polymorphous genera of plants are in a state of disintegration, there is a large amount of good material to be had. G. L. G.

12. *Contributions from the Gray Herbarium of Harvard University. New Series, No. XXXVI, May 1909.*—This number is given up to Mexican and Tropical American Phanerogams, and comprises eight papers. Miss Alice Eastwood gives a synopsis of the Mexican and Central American species of *Castilleja*, 54 in all. Professor Robinson deals with the genus *Rumfordia* and with a number of tropical phanerogams, some of which are new and are now for the first time described, while others are transferred to their proper place in the system. Mr. H. H. Bartlett treats of the American species of *Litsea*, the Mexican and Central American Alders, the southern *Androcerae*, and certain other southern flowering plants. These papers are published as No. 21 of Vol. XLIV of the Proceedings of the American Academy of Arts and Sciences, Boston. G. L. G.

13. *Elemente der exakten Erblichkeitslehre*, von W. JOHANNSEN, Professor in Kopenhagen. Pp. vi, 515. Jena, 1909. (Gus-

tav Fischer.)—This volume of about 500 pages contains the German translation of twenty-five lectures on heredity treated from the modern standpoint of biometry. The author apologizes for bringing so much that is mathematical into these discussions, but he claims that he has reduced the mathematical difficulties to a minimum. Certainly he has presented the subject with thoroughness, and has not avoided the hard parts of what is essentially a very recondite matter. The historical development of the subject takes it for granted that the reader (or hearer) prefers to begin with nothing much farther back than Darwin and Wallace, although the author refers to Lamarck and others before him. Hence this treatise is practically an exhaustive résumé of recent work, and as such will command serious attention from all students of Genetics. The literature of heredity, of late, has expanded enormously, and with comparatively little repetition except in necessary citation, and promises to occupy soon the greater part of the field of biology. In reading the most recent works on this subject, one can hardly fail to be struck by the important bearing the study of descent has upon the hard and fast lines of many species which seemed to be safe within the conventional limits. The examination of variant forms in polymorphous groups is working present havoc in systematic biology, and no one dares longer to give the number of species belonging to a genus; but it is all in the direction of advance. The present work by Professor Johannsen is a long step in that direction.

G. L. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Publications of the U. S. Coast and Geodetic Survey*, O. H. TITTMANN, Superintendent. Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Maryland, 1901–1904; by DANIEL L. HAZARD. Pp. 206, 56 figures. The same at Baldwin, Kansas, 1901–1904. Pp. 138, 4 figs.; at Sitka, Alaska, 1902–1904, pp. 129, 52 figs.; at Honolulu, Hawaii, 1902–1904, pp. 130, 53 figs.; at Vieques, Porto Rico, 1903–1904; pp. 70, 2 figs.—The series of volumes, noted above, has recently been issued giving the results of observations made at our various magnetic observatories. It was not until 1899 that the Government appropriations were such as to allow of a systematic magnetic survey of the country, and the establishment in connection with this of magnetic observatories. The first complete observatory at Cheltenham, Md., 14 miles southeast of Washington, was begun in 1900 and completed in April, 1901. Observations were also made at Baldwin, Kansas, beginning in June, 1900, and in 1901 observatories were constructed at Sitka, Alaska, and near Honolulu, the records of which began in 1902. In February, 1903, observations were begun at Vieques, Porto Rico, where, four years later, a special building was con-

structed. The five volumes by Daniel L. Hazard of the division of terrestrial magnetism give the details in regard to these several stations, with the observations that have been carried on through 1904. An interesting series of charts is included giving the records of magnetic storms, some of them of exceptional intensity, which can thus be compared at the different points.

2. *Hypsometry: Precise Leveling in the United States, 1903–1907. With a Readjustment of the Level Net and Resulting Elevations;* by JOHN F. HAYFORD and L. PIKE. Pp. 280.—Following the publications on leveling by the U. S. Coast and Geodetic Survey, given in Appendix 8 for 1899 and Appendix 3 for 1903, the present paper gives in detail the progress made in developing the level-net over the country. Since 1903, 2,500 miles of leveling have been added by the Survey, and 1700 miles by other organizations. Of these, two lines in Minnesota and two in Louisiana, with a total length of 314 miles, are spurs from the net, while all other lines form links, or parts of links, of the net itself. A special chart shows the status of the net for 1907.

3. *Bureau of American Ethnology, Smithsonian Institution.*—The following publication has been recently issued:

Bulletin 34. Physiological and Medical Observations among the Indians of Southwestern United States and Northern Mexico; by ALEŠ HRDLIČKA. Pp. ix, 400 with 27 plates and 2 figures. Washington, 1908.

4. *The Museum of the Brooklyn Institute of Arts and Sciences.*—The following has been recently issued:

Science Bulletin, Vol. I, No. 15. New Coleoptera, chiefly from Arizona; by CHARLES SCHAEFFER. Pp. 375–386. April, 1909.

5. *Report of Proceedings of the American Mining Congress.* Pp. 268. Denver, 1909.—This volume gives a report in detail (pp. 1–122) of the proceedings at the eleventh annual session of the American Mining Congress held at Pittsburg, December 2–5, A series of papers, beginning with the annual address of the president, Hon. J. H. Richards of Boise, Idaho, fill the 268 pages of the second part. Among the papers may be mentioned accounts of the mineral resources of Arkansas, Arizona, Virginia and Alaska, and also a series on the conservation of mineral resources, conservation in the coal and mining industries, etc.

6. *Publication of the Works of Amedeo Avogadro.*—The year 1911 will be the one-hundreth anniversary of the publication of Avogadro's classic memoir upon the molecular constitution of gases. The Royal Academy of Sciences at Turin proposes to celebrate the occasion by the publication of a volume containing his most important works and by the erection of a monument to him at Turin. The Committee of the Academy appeals to all chemists and physicists to aid in this movement to honor the memory of a man to whom Science owes a great debt. The President of the Executive Commission is Sen. Enrico D'Ovidio of Turin. The members of the Committee in the United States include the following: F. W. Clarke, W. W. Coblentz, Ar.

Michael, A. A. Michelson, E. W. Morley, J. U. Nef, A. A. Noyes, F. Nichols, I. Remsen, Th. W. Richards.

7. *Proposed Publication of the Works of Leonhard Euler.*—The Swiss Society of Natural Sciences has issued a circular asking for contributions to aid in the publication of a complete edition of Euler's Works; these may be made either as definite donations or as annual contributions for a series of years. It is planned to issue 40 volumes at a maximum cost of 25 francs. The entire amount needed is estimated at 400,000 francs, of which it is thought that 150,000 francs will be realized from the sale of the books. This important movement has the sanction of the International Congress of Mathematicians, the German Mathematical Association, the French Academy of Sciences and other scientific bodies.

Donations, as also subscriptions for the volumes as issued, should be sent promptly to the President of the Euler Committee, Prof. Dr. F. Rudio, Dolderstrasse 111, Zürich V., Switzerland.

8. *Prizes offered by the Austrian Society of Engineers and Architects.*—The Österreichischer Ingenieur und Architekten-Verein at Vienna offers prizes of 3000, 1000 and 500 krone for the solution of the following problem: "Wie schützt man sich vor den schädlichen Wirkungen der in den Wechselstromnetzen dauernd oder zeitweilig auftretenden sogenannten höheren Harmonischen der Strom- und Spannungswellen oder wie unterdrückt man deren Entstehen überhaupt?"

Solutions must be handed in on October 1, 1910. The special conditions attached to the contest may be learned on application to the management of the Society at 9 Eschenbachgasse, Vienna I, Austria.

9. *Psycho-Biologie et Énergetique, Essai sur un Principe de Méthodes intuitives de Calcul;* par M. Charles Henry. Pp. 216, with 63 figures. Paris, 1909 (A. Herman et fils, 6 rue de la Sorbonne).—This is a mathematical discussion, having as its object the application of the principles of energy to the relations existing between the senso-motor reactions of an organism to its excitant.

10. *Die Einheit des physikalischen Weltbildes;* von Professor Max Planck of Berlin. Pp. 38. Leipzig, 1909 (S. Hirzel).—The address held on December 9, 1908, before the scientific faculty at the University of Leiden is given in this little pamphlet. It deals chiefly with the subject of conservation of energy and its application to thermodynamics.

11. *Phrenology: or the Doctrine of the Mental Phenomena;* by J. G. Spurzheim, with an introduction by Cyrus Elder. Revised edition from the second American edition, in two volumes, published in Boston in 1833. Pp. 459, with 14 plates. Philadelphia and London, 1908 (J. B. Lippincott Co.).—"An accessible authoritative statement of the principles of Phrenology is needed, and will be found in the following treatise, which is as simple, clear, and logical as any elementary work in any other science." Introduction, p. 29. W. R. C.

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[FOURTH SERIES.]

Art. XI.—*On the Electric Arc between Metallic Electrodes;*[*]

by W. G. Cady and G. W. Vinal.

Second Paper.—*Theory and Production of Oscillations between Arc and Glow.*

§ 1. In the first paper[†] it was shown that in the electric arc at small currents, under certain conditions, the current instead of remaining constant is subject to pronounced and rapid changes. These results proved that Lecher's conclusions regarding the continuity of the electric arc can no longer be accepted without modification.

The method described in the first paper for testing the continuity of the arc discharge consisted essentially in the use of a bolometer connected in parallel with a self-inductance in the arc circuit. It was found that when the bolometer circuit, consisting of a Wheatstone bridge with a fine Wollaston wire of 10 ohms resistance as one arm, was entirely disconnected from the arc circuit, the galvanometer of the bridge sometimes showed a deflection. As this occurred even when the two circuits were a meter apart, it was evident that oscillations of considerable frequency and intensity must be taking place in the arc.

The study of these oscillations forms the subject matter of the second and third papers. It will be dealt with under the following heads:

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[*] This investigation was carried on with the aid of a grant from the Elizabeth Thompson Science Fund.

[†] W. G. Cady and H. D. Arnold, this Journal, clxxiv, p. 383, 1907. Some months after the appearance of our first paper, Buisson and Fabry (C. R., cxlviii, p. 1143, 1908) also announced their discovery of the first and second stages in the iron arc.

I. Theory of the glow-arc oscillations (§§ 2 to 7).

II. Best conditions for the production of the oscillations (§§ 8 to 12).

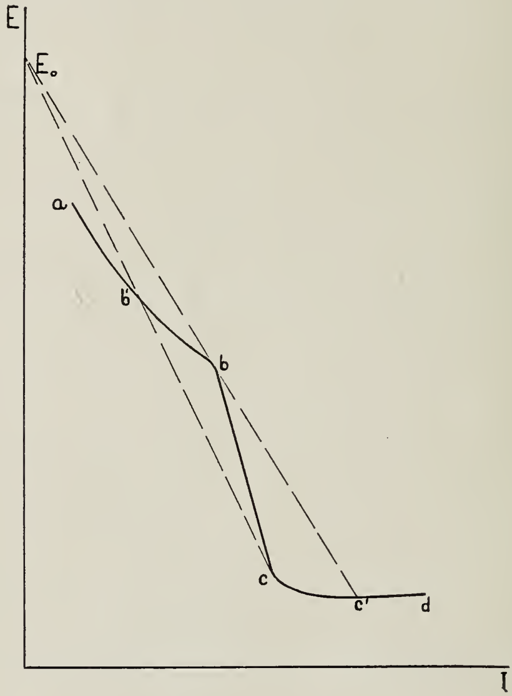
III. Experimental evidence of the existence of glow-arc oscillations (§§ 13, 14).

IV. Properties of the oscillations (§§ 15 to 32).

I. THEORY.

§ 2. For the sake of clearness the theory which offers the most satisfactory explanation of the oscillations is set forth here, the experimental evidence in its favor being for the most part reserved until later.

FIG. 1.



Let us suppose that we have a circuit consisting of an electromotive force of several hundred volts, large resistance capable of fine adjustment, and a short gap between metallic terminals in free air. Then, as is well known, the discharge will be either in the form of a glow, with a characteristic curve represented by the line *ab* in fig. 1, or an arc, represented by *cd*. *bc'* is the unstable interval over which the discharge springs in passing from glow to arc, *cb′* the interval traversed in the reverse direction.* The slope of the line *bc′* is determined by E_0, the supply electromotive force.

Let the resistance initially be relatively small, so that the arc is stable at *d*. As the resistance is now increased, there comes a point where the energy at the cathode is too small to maintain vaporization, and the discharge changes suddenly along *cb′* to a glow. The anode may or may not be in a state of vaporization. Generally the anode ceases to vaporize before the cathode ("first stage" of our former paper). The oscillations dealt with here are a purely cathode phenomenon, and the material of the anode is of no consequence.

If the line *cb′* is steep (high impressed electromotive force) then it may be that the energy expended at the cathode at *b′* is greater than that at *c*. If conditions are such that the heat is largely confined to the neighborhood of the cathode, the temperature of the negative terminal rises rapidly, so that the part *b′b* of the characteristic, possibly somewhat modified on account of high temperature, is automatically traversed, until evaporation sets in, an arc forms along *bc′*, and the cycle repeats itself again. The period of this cycle is exceedingly variable, depending upon a large number of factors, of which the chief are nature and form of cathode, means of disposing of heat, distance between electrodes, nature and pressure of gas, electromotive force and resistance of the circuit, and, as will be seen, the self-inductance and capacity of the circuit considered as a system capable of performing electrical oscillations.

§ 3. For example, with a supply of 460 volts, using copper electrodes, free from oxide, one to two mm. in diameter, in free air, the discharge can be made to pulsate irregularly between arc and glow with a period of from one-half second to several seconds. On the glow phase the negative mantle covers the end of the electrode, which becomes incandescent for a considerable distance from its tip before vaporization sets in.

If now the gap is shortened and the current diminished, the glow will take place in gas left ionized by the arc, and confined in the narrow space between the electrodes. The negative mantle will occupy approximately the area of the negative base of the arc, and the temperature of this small area will rise very rapidly. This hastens vaporization and shortens the glow phase. Since the energy available for the maintenance of vaporization on the arc phase is now very small, the duration of the arc is also much reduced. The discharge then pulsates with a frequency which may reach into the thousands between the two phases, the temperature of the cathode surface varying

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* Cf. Kaufmann, Ann. Phys., ii, p. 162, 1900; also our first paper, p. 395.

between the boiling point of the material and one very slightly below it. This local heating is now largely dependent on the condition of the cathode surface, and the period will fluctuate as the discharge wanders from point to point over this surface. The oscillations which we recorded photographically, using copper electrodes in air, are to be regarded as an instance of this sort (§ 9).

§ 4. In order further to increase the rapidity of the pulsations, attention must be paid to the surrounding gas. As will be seen (§ 10), when a suitable gas is chosen, the current reduced to the right extent, and the distance between electrodes made very small, the period of the pulsations is determined chiefly by the electrical constants of the circuit. In other words, high-frequency electrical oscillations take place, governed by the resistance, self-inductance, and capacity, concentrated or distributed, of the arc circuit, which react upon the discharge, and control its periodicity. The discharge then imparts energy to the oscillations as the escapement of a clock imparts energy to the pendulum. The material of the cathode may affect the intensity and permanency of the oscillations, but not their frequency.

In this respect the glow-arc discharge is analogous to the spark-gap, except that it seems to consist of undamped oscillations (§ 29). It is also analogous to the oscillating arc of the Thomson-Duddell type, whose period of oscillation depends essentially on the capacity and self-inductance in parallel with it. The distributed self-inductance and capacity of the glow-arc discharge circuit itself correspond to the self-inductance and capacity in parallel with the Duddell arc, and the steep slope of the line *bc′* (fig. 1) to the "falling" characteristic of Duddell.

High-frequency oscillations of the Duddell type, in which the only self-inductance and capacity were those of the electrodes and adjacent parts of the circuit, have been described by Stschodro* and Simon†, but in each of these cases a stable arc of the ordinary sort seems to have been used.

§ 5. During the passage of the oscillations the discharge circuit itself behaves like an open oscillator, radiating energy. Thus it is possible to obtain energy from the discharge in either one of two ways, viz.: by coupling a coil in the circuit inductively with a secondary coil outside, or by making use of the electromagnetic waves radiated from the various parts of the circuit. The former method was used in our frequency determinations. The radiations will be considered in § 32.

* Stschodro, Ann. Phys., xxvii, p. 225, 1908.

† Simon, Phys. Zeitschr., ix, p. 872, 1908.

§ 6. The net result of the glow-arc pulsations is the transformation of a portion of the direct current energy into that of an alternating current, giving rise to an alternating current superposed upon the direct current. In this respect the discharge behaves like a microphone contact, or like a current interrupter. Such cases may be treated either as pulsating resistances or as alternating electromotive forces.* Suppose, for example, that a constant electromotive-force E sends a current I through a circuit of self-inductance L, constant resistance R, and pulsating resistance $aR \cos pt$. Then

$$E = L\frac{dI}{dt} + IR\,(1 + a \cos pt).$$

This case is discussed by Barkhausen (l. c.), who by a process of successive approximations arrives at the conclusion that the current wave is of a form represented by a fundamental vibration with a system of higher harmonics. The equation has been exactly solved for another purpose by Mr. L. Cohen, to whom the writers are indebted for his kind permission to make use of the solution. In a paper shortly to be published by Mr. Cohen it will be shown that

$$I = \frac{E}{R}\left\{ 1 + \frac{Ra}{\sqrt{2(R^2+p^2L^2)}} \cos(pt - \phi) - \frac{R^2a^2 \cos(2pt - \psi_1 - \psi_2)}{2\sqrt{(R^2+p^2L^2)(R^2+4p^2L^2)}} + \ldots \right\}$$

where ϕ, ψ_1, ψ_2, are constants.

For the present purpose the most noteworthy feature about this solution, beside the existence of the harmonic terms, is the fact that the greater the value of a, that is, the greater the amplitude of the variable resistance, the more slowly does the series converge. This helps account for the intensity of the higher harmonics that are recorded below (§ 25). The equation just quoted fails to take into account two facts: first, that the capacity of the circuit plays an important part in the case of oscillations of high frequency, and second, that the resistance of the electric discharge does not pulsate sinusoidally, but in a much more complex manner.

§ 7. Of the relative durations of the arc and glow phases we know little, but the shorter one of these is in relation to the other, the more pronounced must the harmonic terms become. In any event the presence of a complex wave form, involving

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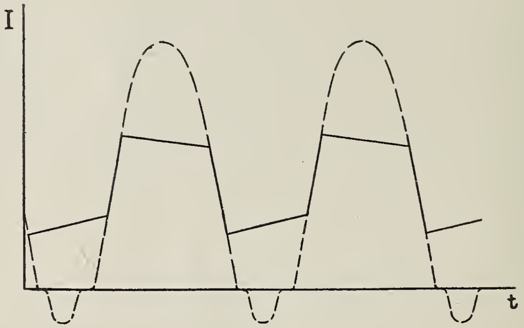
*Barkhausen, Das Problem der Schwingungserzeugung, Leipzig, 1907, p. 19.

a large family of harmonics, may confidently be predicted. Owing to the lack of symmetry between arc and glow phases, both odd and even harmonics may occur (§ 25).

A further complication arises from the fact that since the oscillations adapt their frequency to the natural period of that part of the circuit which they are able to penetrate, a kind of resonance sets in, with the result that *the effective value of the alternating current may be greater than that of the direct current supplied by the generator.*

This shows that for a certain time during each cycle the direction of the current is reversed. It is evident that in order for this to take place the capacity of the arc circuit must play an important rôle. In this respect the oscillations have a slight similarity with the third type of oscillation studied by Blondel in the singing arc.*

Fig. 2.



The form of the current wave must be somewhat as represented in fig. 2. Here the full lines represent the normal current pulsating between arc and glow where the effects of resonance are neglected. The broken lines show the form of the current curve when the pulsations take place in synchronism with the natural period of the circuit. The current on the arc phase rises much higher than before, while the glow phase with the current in the positive direction practically disappears, a brief discharge in the opposite direction taking its place.

If the frequency were lower, the potential difference would have to rise very high in order to re-start the discharge at each reversal, and the result would be practically a succession of sparks. But in view of the high frequency (on the order of a quarter of a million) and of the short distance between the

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* Blondel, l'Écl. Élect., xliv, p. 81, 1905

electrodes, it is clear that the glow phase can begin promptly after each reversal of current.

The frequency is too inconstant to permit of an analysis of the wave form by any of the ordinary types of oscillograph. On the other hand, an estimate of the frequency on theoretical grounds would require a knowledge of the resistance, self-inductance and capacity not only of the circuit, but of the discharge itself. To compute these factors would be difficult, involving as it must an exact knowledge of the extent to which the oscillations penetrate into the circuit.

II. Production and Appearance of Oscillations.

§ 8. The oscillations when strong were detected by means of a bolometer insulated from the arc circuit and 10 to 100^{cm} distant from it. In this case the greater part of the energy received by the bolometer circuit was in the form of electromagnetic radiations from the nearest portions of the discharge circuit. With feeble oscillations like those first described below, it was necessary to connect one point of the bolometer circuit with one terminal of the arc.

Evidences of feeble oscillations were obtained with a copper arc in free air, and with iron and silver arcs in nitrogen. (First paper, pp. 391, 410.) In some of these cases the cathode was also of carbon.

Further study of the copper arc in air has yielded the following results, obtained in general with an e.m.f. of over 400 volts.

For oscillations the copper cathode must be clean and free from oxide. This is in conformity with our earlier observation that no glow discharge is possible from an oxidized electrode. The oscillations can sometimes be detected by the bolometer when the current is as large as one ampere, and they reach their maximum intensity at 0·2 or 0·3 amp. The length of arc may be as large as 2^{mm}, but best results are obtained with a very short gap between the electrodes.

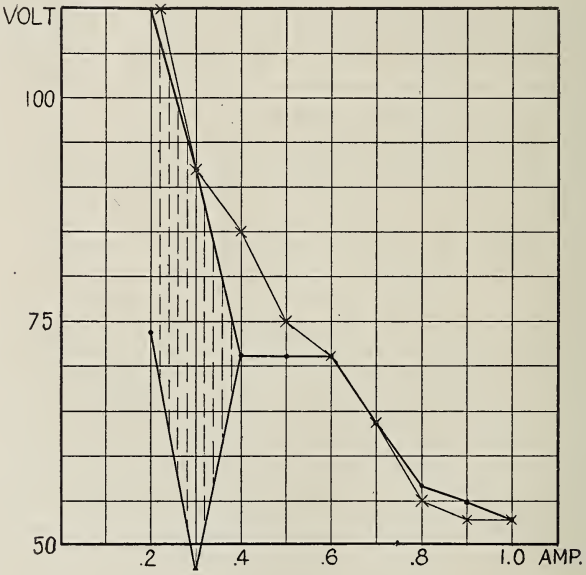
Water-cooled electrodes do not offer an appreciable advantage over those at high temperature. Ample evidence shows that the change from first to second stage at the copper anode has nothing to do with the effect, which is purely a cathode phenomenon. Like effects are produced whether the anode is of copper or carbon.

The beginning of strong oscillations is indicated by the appearance of the discharge, which assumes an aspect intermediate between that of an arc and of a glow. A very characteristic tinkling sound is heard and the needle of the voltmeter connected across the discharge trembles violently and irregularly between two extreme positions.

Fig. 3 represents the characteristic curve of the copper arc in air. The line marked with crosses was obtained when no oscillations were present, probably owing to a trace of oxide on the cathode. The heavy line shows the effects of oscillations, which began in this case at about 0·4 amp. The limits of the shaded area indicate roughly the extreme swings of the voltmeter needle, whose inertia undoubtedly prevented it from reaching the actual extremes of potential, particularly on the glow phase, the duration of which is very short.

Above 0·4 amp. the discharge is a stable arc. At 0·4 amp. the pulsations between arc and glow begin, feebly at first, but increasing in intensity as the current decreases. With a higher supply e.m.f. it would doubtless have been possible by further reducing the current to observe the gradual diminution in intensity until a steady glow was reached. Under whatever conditions the oscillations are obtained they are always of maximum intensity at a certain current.

Fig. 3.



§ 9. In order to throw light on the nature and frequency of these oscillations the image of the arc was allowed to fall on a rapidly moving photographic plate. An arc between a carbon anode and copper cathode in free air was used, the electrodes being horizontal. The photographic plate was allowed to drop through a vertical wooden chute, its motion being accelerated by means of rubber bands until it passed an opening in the chute at a velocity of about 565cm. / sec. = 0·000177 sec. / mm. By means of an achromatic lens a minute image of the arc was formed on the plate as it passed this opening.

A number of plates were dropped under varying conditions of arc, the current being on the order of 0·3 amp. and the length of arc 1^{mm}.

In nearly all cases where the bolometer system showed a deflection the record on the photographic plate was not a continuous line, but broken into a system of more or less periodic dots or dashes. These occurred in trains of from five to several hundred waves, the period being practically constant throughout each train, but varying abruptly from one train to the next. No evidence of damping could be seen.

The lowest frequency observed was about 1,300 per second, the highest about 43,000. In one case a change from a frequency of 1,300 to one of 10,000 took place on the same record. The velocity of the plates and clearness of the image hardly permitted the identification of a frequency higher than 50,000, so it cannot be affirmed that higher frequencies were not present.

These experiments show that in the oscillating carbon-copper arc in free air, the current and the light emitted from the arc are varying constantly with a period which itself is subject to sudden and great variations (cf. § 3).

§ 10. Following is a brief account of experiments made with a view to learning under what conditions the regularity, frequency and intensity of these oscillations can be increased.

In CO_2 *and in N.* Deflections of bolometer small and unsatisfactory.

In H. No arc, but only a glow, could be obtained except when the current was over 0·3 amp.

A little benzine vapor was then introduced by allowing the hydrogen to bubble through a bottle of benzine.* This enabled us to decrease the arc current to 0·2 amp., at which current good oscillations occurred. However the use of benzine was discontinued owing to the copious deposits of soot and to the tendency of the arc to go out.

In illuminating gas. This gave far better results than any of the gases mentioned above. A silver cathode was chiefly used. On account of the deposit of carbon dust from the dissociated gas, the latter was diluted by the addition of a certain amount of nitrogen or air. It was in illuminating gas that large deflections were observed for the first time when the bolometer circuit was entirely disconnected from the arc

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* Cf. Barreca, Electrician, Jan. 17, 1908.

circuit. The effect was decidedly better at atmospheric pressure than at any reduced pressure. No oscillations, however, could be detected when the arc was surrounded by the flame of a Bunsen burner.

In H and acetone vapor. The tests with benzine vapor and with illuminating gas indicated that the presence of hydrocarbons around the arc greatly facilitates the production of oscillations. In the attempt to find a carbon compound that should give rise to less carbon dust, we tried a mixture of hydrogen and acetone, as described by Fischer.* This was produced by passing the hydrogen from a Kipp generator through the upper part of a bottle containing acetone. It was found better not to let the hydrogen bubble through the liquid. In this manner enough acetone vapor was present to permit of strong oscillations without causing a very rapid accumulation of carbon dust. Nevertheless it was necessary to clean the electrodes frequently, and at no time were the oscillations comparable in constancy with those from the spark or Duddell arc. Using the most careful precautions, we could not keep the oscillations from being fickle and irregular. Hardly ever could a resonance curve be obtained without the necessity of bringing the electrodes together, rotating one of them, or otherwise changing the character of the oscillations. Hence the values of frequency given below can be considered only as rough approximations. Nearly all the observations to be described were obtained with the discharge in hydrogen and acetone.

The frequency in illuminating gas or acetone is much greater than in air. The carbon compounds around the discharge seem to make the cathode base, on the glow phase, more concentrated, and thus to accelerate its rise in temperature. The discharge is steadier and more quiet than in air, and the frequency is comparatively constant, being determined by the electrical constants of the circuit (cf. § 4).

§ 11. *Tests with Different Metals.* Any metal, or carbon, may serve as anode, though when carbon is used the production of soot is annoying. As cathode we have tried Pt, Fe, Ag, Cu, Al, Pb, and soft solder. All give initial oscillations of apparently the same intensity and frequency, though alteration of the surface of some of these soon destroys the effect. No difference in frequency could with certainty be detected whether the cathode was of Ag, Cu or Al. A fine copper wire produced the same effect as a large disc. With carbon as cathode only the feeblest oscillations could be observed—though it was with this arrangement that the oscillations were

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* Fischer, Ann. Phys., xxviii, p. 57, 1909.

first discovered. Black oxide of iron, Fe_3O_4, gave feeble oscillations.

§12. When the e.m.f. of the supply was gradually reduced, the oscillations became less intense, and a larger current was found necessary. With a supply of only 145 volts a very feeble deflection of the bolometer was still perceived, the discharge current being 0·8 amp. This deflection may have been due to mere irregularities in the burning of the arc. At any rate, there seemed to be no critical discharge potential at which oscillations suddenly began.

III. EXPERIMENTAL EVIDENCE OF GLOW-ARC OSCILLATIONS.

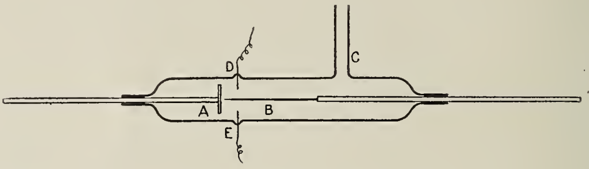
§13. That a gradual transition can be observed from a visible slow change between arc and glow in air, through the more rapid pulsating discharge recorded by photography, to the high-frequency oscillations in hydrogen and acetone, is *à priori* evidence that in these last oscillations the change between arc and glow is still taking place. The alternative hypothesis, that of an intermittent spark discharge, is, of course, obvious, and indeed it may be that a gradual transition from glow-arc pulsations to a pure spark discharge, by raising the e.m.f. and at the same time decreasing the current, could be accomplished. That the present phenomenon is not a spark discharge in the ordinary sense is rendered probable by the small damping of the oscillations (§29). Moreover, if this were a spark discharge, the train of waves that constituted each spark dying down nearly to zero before the next discharge passed, then in order to explain the observed fact that the effective total current is several times as large as the mean direct current, we should have to assume a very large initial amplitude. But this would be hard to reconcile with the relatively low impressed e.m.f.

§14. According to the explanation of the oscillations here advanced, the potential drop across the discharge must rise to that characteristic of a glow-discharge once during each period. It was determined to test this, and at the same time to answer the question as to whether the oscillations might be due to a rapid succession of short sparks. For in the latter case, the potential difference would be expected to rise considerably above that of a glow discharge.

Considering the high frequency of the oscillations, the only available method for measuring the maximum potential difference seemed to be to connect across the discharge a calibrated spark-gap. That this method is applicable even when the frequency is as high as one million follows from the work of Voege* and Algermissen,† especially as the latter writer shows that for short spark lengths the high-frequency discharge potential differs but little from the static potential.

The spark-gap used consisted of a brass plate *A* (fig. 4) 1^{cm} in diameter, which served as anode, and as cathode a small steel sewing needle *B*. These electrodes were mounted about 1^{mm} apart in a small glass tube, and were sealed in with sealing-wax. A side arm *C* from the tube communicated with a hydrogen generator, air-pump, and manometer. The copper arc in a mixture of hydrogen and illuminating-gas at atmospheric pressure was employed as the source of oscillations. Short, thick wires connected the arc terminals with the spark-gap.

Fig. 4.



Great difficulty was at first experienced in causing a spark to pass promptly at sufficiently low potential. An iron arc, and later a powerful spark between zinc electrodes, placed close to the glass tube, did not materially help matters, nor did ionizing the gas in the tube directly by running the discharge from a small induction-coil from point to plate just before each observation.

It then occurred to us to keep the gas artificially in a state of ionization while the sparking potential was being applied. To this end two platinum wires *D*, *E* were sealed into the tube on opposite sides of the spark-gap, about 5^{mm} in front of the brass disc. The terminal *A* was kept constantly connected to the positive terminals of the arc and of a variable e.m.f. for calibrating. *B* could be connected in rapid succession to the negative terminal of the calibrating e.m.f. (through a high resistance), and to the cathode of the arc. Observations were carried out thus: the gas in the tube was exhausted to a certain pressure, the auxiliary discharge from a small induction coil started between *D* and *E*, and the lowest static potential observed that just sufficed to start a discharge between *A* and *B*. *B* was then quickly connected to the cathode of the arc, and it was noted whether or not a discharge between *A* and *B* took place. The discharge between *D* and *E* was

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* Voege, Elektrot. Zschr., xxv, p. 1033, 1904.
† Algermissen, Ann. Phys., xix, p. 1016, 1906.

maintained throughout this operation. Then the pressure in the tube was varied and the observations repeated. Each variation of gas pressure of course changed the minimum sparking potential, so that after a series of such observations it was possible to set a sufficiently close upper limit for the maximum potential drop across the arc.

The lowest discharge potential observed in this way from the calibrating circuit was 340 volts, the gas pressure in the spark tube being about 7^{mm}. With a 460 volt supply e.m.f. for the arc, the maximum potential drop across the arc when oscillations were present was always found to be at least 340, usually about 385, but never higher than 397 volts.

These values are hardly greater than what would be expected for the drop across the terminals of a short glow discharge, where the greater part of the total drop is that at the cathode. Hence, in so far as the spark-gap method is permissible in the case of high-frequency oscillations, it seems proven that the discharge is not intermittent and discontinuous, but consists of an exceedingly rapid change back and forth between arc and glow.

The use of auxiliary ionizing electrodes is in every way to be recommended for work of this sort. By their aid, the response of the tube to an applied voltage above the minimum is instantaneous, while the minimum discharge potential itself is sharply defined and well reproducible. The presence of the auxiliary ionizing discharge did not seem to make the critical discharge potential lower than it was after the usual lag with no artificial ionization.

SUMMARY.

I. The theory of a type of pulsating discharge, called for convenience the "glow-arc" discharge, is explained. This is a spontaneous and rapid change back and forth between arc and glow, whose essential feature is that the rate of expenditure of energy at the cathode on the glow phase is greater than that on the arc phase. Under suitable conditions the frequency of these oscillations is so great that they take place in synchronism with the natural period of the neighboring portion of the discharge circuit, as determined by its resistance, self-inductance, and capacity, distributed or concentrated. An oscillating current is thus generated, whose intensity may be greater than that of the supply current. It is shown that higher harmonics must be prominent in the current wave.

II. The conditions for best oscillations were investigated. The copper arc in air gives pulsations slow enough to be recorded on a photographic plate, but the oscillations are most rapid and powerful when the discharge takes place in a mixture of hydrogen and acetone vapor.

III. Strong evidence in favor of the glow-arc hypothesis is derived from the measurement of the maximum potential difference assumed by the discharge during each cycle. By means of a calibrated spark-gap it was found that this maximum does not rise above that characteristic of a glow discharge. A new method was employed for keeping the gas in the neighborhood of the spark-gap in a state of ionization.

Scott Laboratory of Physics,
Wesleyan University,
June 3, 1909.

[To be continued.]

Art. XII.—*The Heat of Formation of Trisodium Orthophosphate, Trisodium Orthoarsenate, the Oxides of Antimony, Bismuth Trioxide; and fourth paper on the Heat of Combination of Acidic Oxides with Sodium Oxide;* by W. G. Mixter.

[Contributions from the Sheffield Chemical Laboratory of Yale University.]

The heat of combination of an acidic oxide with sodium oxide may be derived from the heat of formation of the anhydrous salt, and, conversely, the thermal effect of the union of the elements in a salt may be calculated from the heat of combination of the oxides forming it. Only the latter method is applicable to insoluble salts of weak acids, as, for example, sodium antimonate. The investigation includes new determinations of some constants and the results obtained agree with those of other investigators and show the value of the sodium-peroxide method.

Kilogram-calories, which are indicated by the decimal point, are used in some of the calculations for sake of brevity. The gram-calorie is, however, more philosophical, as the gram is the unit of mass in physical science and quantities in chemistry are commonly expressed in grams. Unless otherwise indicated, the constants used in the calculations are Thomsen's and are taken from his Thermochemistry, the English translation by Katharine A. Burk.

Trisodium Orthophosphate.

The red phosphorus for the work was digested with hot dilute nitric acid, next with a concentrated solution of sodium hydroxide and then washed and dried. When exposed to moist air for twenty-four hours, it gained in weight 0·16 per cent. The following are the experimental data:

	1	2
Phosphorus	1·000 gram	1·000 gram
Sodium peroxide	12 "	13 "
Water equivalent of system	4,136 "	3,999 "
Temperature interval	1·986°	2·004°
Heat observed	8,214^{c}	8,014^{c}
" of oxidation of iron	—48^{c}	—48^{c}
For 1 gram of phosphorus	8,166^{c}	7,966^{c}

In the first experiment the mixture was in a silver cup the rim of which only was in contact with the cold sides of the bomb. With this arrangement the fusion cools slowly and the reaction is more complete than without the inner cup, as was the case in the second experiment. Using the first result we have

$5Na_2O_2 + 2P\,(8166 \times 62) = 3Na_2O,P_2O_5 + 2Na_2O +$ 506,292^c
$5Na_2O + 5O = 5Na_2O_2 +$ .... 97,000^c*
$3Na_2O + 2P + 5O = 3Na_2O,P_2O_5 +$ .... 603,292^c
$2P + 5O = P_2O_5 +$ .... 369,900^c
$3Na_2O + P_2O_5 = 3Na_2O, P_2O_5 +$ .... 233,392^c

In the Physikalisch-Chemischen Tabellen with reference to Berthelot† $3Na,P,4O = 452{\cdot}4^c$, from which is derived $235{\cdot}5^c$ for the heat effect of $Na_2O + P_2O_5$. Berthelot‡ and Thomsen both found the heat of neutralization of phosphoric acid by sodium hydroxide to be 34·0. From this we derive Na,P,O_4,-$Aq = 469{\cdot}5^c$. Joly§ gives the following: $Na_3PO_8\,24HO = -14{\cdot}5^c$ and $Na_3PO_8 + 24HO = +48{\cdot}1^c$. $(O = 8.)$ The heat of solution of Na_3PO_4 is the sum of these numbers, i. e., $33{\cdot}6^c$. The experimental data are not given and the writer does not understand the result, which is apparently twice too high. Subtracting one-half of it, $16{\cdot}8^c$, from $469{\cdot}5^c$ we have $Na_3,P,O_4 = 452{\cdot}7^c$, which is essentially the same as given in the Physikalisch-Chemischen Tabellen, as stated above.

From the result of experiment 1 we have

$3Na_2O + 2P + 5O = 2Na_3PO_4 +$ .... 603·3^c
$6Na + 3O = 3Na_2O + (99{\cdot}8 \times 3) +$ .... 299·4^c
$2(3Na + P + 4O) =$ .... 902·7^c
$3Na + P + 4O =$ .... 451·4^c

The heat of formation of sodium phosphate found by the two methods is $452{\cdot}7^c$ and $451{\cdot}4^c$, and hence the heat of combination of sodium oxide with phosphorus pentoxide obtained by the different methods is, essentially, the same.

Trisodium Orthoarsenate.

The arsenic for the following experiments was sublimed and then heated in a current of dry hydrogen in order to remove any oxide present.

	1	2	3
Arsenic	5·000 gr.	5·000 gr.	6·000 gr.
Sodium peroxide	23 "	19 "	22 "
Water equivalent of system	4,028 "	3,945 "	3,994 "
Temperature interval	2·667°	2·865°	3·247°

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* De Forcrand, C. R., cxxvii, 514.
† Ann. Ch. Phys. (5), ix, 28.
‡ Loc. cit.
§ C. R., civ, 1704.

Heat observed	10,743^c	11,309^c	12,969^c
" of oxidation of iron	—48^c	—48^c	—48^c
" " oxygen absorbed	—58^c	—90^c	—67^c
	10,637^c	11,171^c	12,854^c
For 1 gram of arsenic	2,127^c	2,234^c	2,132^c

The mean of the results is 2,168^c and for 150 grams of arsenic it is 325·2^c. The heat of combination of sodium oxide with arsenic pentoxide is derived thus:

$5Na_2O_2 + 2As = 3Na_2O, As_2O_5 + 2Na_2O +$ .... 325·2
$5Na_2O + 5O = 5Na_2O_2 +$ .... 97·0
$3Na_2O + 2As + 5O = 3Na_2O, As_2O_5 +$ .... 422·2
$2As + 5O = As_2O_5$ .... 219·4
$3Na_2O + As_2O_5 = 3Na_2O, As_2O_5 +$ .... 202·8

Two determinations of the heat of union of arsenic pentoxide with sodium oxide gave for 1 gram of the former 792^c and 867^c respectively. The combustions were not satisfactory, as a little sodium arsenite was formed. Using the higher result, we have 867×230 = 194,400^c for the heat effect of $3Na_2O+As_2O_5$.

The heat of formation of trisodium orthoarsenate is derived as follows:

$3Na_2O + 2As + 5O = 2Na_3AsO_4 +$ .... 422·2
$3Na_2 + 3O = 3Na_2O +$ .... 299·4
$2Na_3, As, O_4 =$ .... 721·6^c
$Na_3, As, O_4 =$ .... 360·8^c

The heat of formation of trisodium arsenate in solution calculated from Thomsen's heat of neutralization of arsenic acid is 381·3; subtracting 17·7, the heat of solution of Na_3AsO_4 (Joly),* gives 363·6 for Na_3, As, O_4.

Antimony.

A mixture of pulverized antimony and sodium peroxide does not burn throughout the mass when kindled at one point, hence sulphur or some other substance must be added to the mixture to furnish the heat required to effect the combustion. The following are the experiments:

	1	2
Antimony	10·000 grams	10·000 grams
Sulphur	1·000 "	1·000
Sodium peroxide	31 "	30 "
Water equivalent of system	4,028 "	4,222
Temperature interval	4·384°	4·208°

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* C. R., civ, 1704.

Heat observed	17,660^c	17,766^c
“ of oxidation of sulphur	$-5,271^c$	$-5,271^c$
“ “ “ “ iron	-48^c	-48^c
“ “ oxygen absorbed	-60^c	-72^c
	12,281^c	12,375^c

The mean result for 240·4 grams of antimony is 296,300^c. As an excess of sodium oxide was present in the fusions Na_3SbO_4 must have been formed, hence we have

$5Na_2O_2 + 2Sb + 2Na_3SbO_4 + 2Na_2O +$ .... 296,300^c
$5Na_2O + 5O =$ .... 97,000^c
$3Na_2O + 2Sb + 5O = 2Na,SbO_4 +$ .... 393,300^c

Antimony Pentoxide.

The preparation of the pentoxide was made as follows: antimony was completely oxidized by prolonged digestion with hot concentrated nitric acid, and the antimonic acid obtained was washed to remove soluble impurities. It was converted into oxide by heating in an electric furnace until the weight remained constant at about 400°. The product was allowed to cool in a closed tube, as antimony pentoxide absorbs water from the air. It was free from a lower oxide and 1·7662 grams yielded 1·6784 grams of Sb_2O_4, which is equivalent to 1·7662 grams of Sb_2O_5. For the following experiments antimony pentoxide was weighed in a stoppered bottle and mixed with the sulphur and sodium peroxide in a closed bomb.

	3	4	5
Antimony pentoxide	10·059 gr.	10·007 gr.	10·673 gr.
Sulphur	2·000 “	2·000 “	2·000 “
Sodium peroxide	21 “	23 “	21 “
Water equivalent of system	4,100 “	4,028 “	4,034 “
Temperature interval	3·789°	3·834°	3·900°
Heat observed	15,535^c	15,444^c	15,733^c
“ of oxidation of sulphur	$-10,542^c$	$-10,542^c$	$-10,542^c$
“ “ “ “ iron	-48^c	-48^c	-48^c
“ “ oxygen evolved	$+151^c$		$+359^c$
	5,096^c	4,854^c	5,502^c
For 1 gram of Sb_2O_5	507^c	485^c	515^c

The result of 4 should not be included in the final value as the oxygen evolved was lost. The mean of the other two is 511 and for 320·4 grams it is 163,700^c.

Antimony Trioxide.

Antimony trioxide was made by treating the trichloride with dilute ammonia, washing the product thoroughly and then heating it out of contact with air as long as water came off. It was free from a higher oxide.

The experimental data are as follows:

	6	7	8
Antimony trioxide	9·985 gr.	10·318 gr.	8·994 gr.
Sulphur	2·000 "	1·800 "	2·200 "
Sodium peroxide	28 "	25 "	28 "
Water equivalent of system	4,110 "	4,097 "	4,182 "
Temperature interval	4·190°	4·008°	4·209°
Heat observed	17,221^c	16,417^c	17,602^c
" of oxidation of sulphur	−10,542^c	−9,488^c	−11,596^c
" " " " iron	−48^c	−48^c	−48^c
	6,631^c	6,881^c	5,958^c
For 1 gram	664^c	667^c	662^c

The oxygen absorbed or evolved in each of the combustions was insignificant. Different mixtures were taken in order to learn whether or not the thermal result is influenced by the proportions of antimony trioxide, sulphur and sodium peroxide. The fact that the results are the same indicates that the same sodium antimonate was formed in each instance.

The mean of the experiments is 664 and for one gram molecule of antimony trioxide it is 191,500^c.

Antimony Tetroxide.

Antimony tetroxide was made by heating antimonic acid in an electric furnace until the product did not lose weight at a dull red heat. In the following experiments the absorption of oxygen was insignificant:

	9	10
Antimony tetroxide	10·233 grams	7·386 grams
Sulphur	2·000 "	2·000 "
Sodium peroxide	23 "	22 "
Water equivalent of system	4,161 "	4,180 "
Temperature interval	3·871°	3·486°
Heat observed	16,107^c	14,571^c
" of oxidation of sulphur	−10,542^c	−10,542^c
" " " " iron	−48^c	−48^c
	5,517^c	3,981^c
For 1 gram	539^c	539^c

The result for 304·4 grams of antimony tetroxide is 164,100^c.

In all of the combustions of antimony and its oxides the oxidation was complete and no antimonite was formed. The solutions of the fusions were tested adding silver nitrate and then ammonia. No black substance remained, proving that an antimonite was not present. The insoluble residues from the fusions when treated with a boiling solution of potassium hydroxide, silver nitrate and ammonia also yielded no black substance. The insoluble residues mentioned even after long digestion with water reacted alkaline, showing that the hydrolysis of the sodium antimonate was not complete.

The heat of formation of the oxides of antimony is derived from the experimental results as follows :

$3Na_2O + 2Sb + 5O = 2Na_3SbO_4 +$ .... 393·3
$3Na_2O + Sb_2O_5 = 2Na_3SbO_4 +$ .... 163·7

$2Sb + 5O = Sb_2O_5 +$ .... 229·6

$2Na_2O_2 + Na_2O + Sb_2O_3 = 2Na_3SbO_4 +$ .... 191·5
$2Na_2O + 2O = 2Na_2O_2 +$ .... 38·8

$3Na_2O + Sb_2O_3 + 2O = 2Na_3SbO_4 +$ .... 230·3
$3Na_2O + Sb_2O_5 = 2Na_3SbO_4 +$ .... 163·7

$Sb_2O_3 + 2O = Sb_2O_5 +$ .... 66·6

$Na_2O_2 + 2Na_2O + Sb_2O_4 = 2Na_3SbO_4 +$ .... 164·1
$Na_2O + O = Na_2O_2 +$ .... 19·4

$3Na_2O + Sb_2O_4 + O = 2Na_3SbO_4 +$ .... 183·5
$3Na_2O + Sb_2O_5 = 2Na_3SbO_4 +$ .... 163·7

$Sb_2O_4 + O = Sb_2O_5 +$ .... 19·8

$2Sb + 5O = Sb_2O_5 +$ .... 229·6
$Sb_2O_4 + O = Sb_2O_5 +$ .... 19·8

$2Sb + 4O = Sb_2O_4 +$ .... 209·8

$2Sb + 5O = Sb_2O_5 +$ .... 229·
$Sb_2O_3 + 2O = Sb_2O_5 +$ .... 66·

$2Sb + 3O = Sb_2O_3 +$ .... 163·0

Thomsen derived the heat of formation of antimonic acid from that of the pentachloride and the heat effect of the hydrolysis of it and obtained $Sb_2, O_5, 3H_2O = 228{\cdot}8^c$, the writer found that $Sb_2, O_5 = 229{\cdot}6^c$. The difference between these two numbers is within the limits of error. Thomsen stated that the antimonic acid was free from chlorine and the writer has also found that the hydrolysis of antimony pentachloride is complete. Evidently the heat effect $Sb_2O_5, 3H_2O$ is quite small, as might be expected, since As_2O_5, $3H_2O = 6{\cdot}5^c$ only, while P_2O_5, $3H_2O = 30{\cdot}6^c$.

In conclusion it may be stated that the heat of formation of trisodium antimonate from its elements is $346{\cdot}4^c$, and is derived as follows:

$3Na_2O + 2Sb + 5O = 2Na_3SbO_4 +$ .... $393{\cdot}3^c$
$6Na + 3O = 3Na_2O +$ .... $299{\cdot}4^c$
$6Na + 2Sb + 8O = 2Na_3SbO_4 +$ .... $692{\cdot}7^c$
$3Na + 2Sb + 4O = Na_3SbO_4 +$ .... $346{\cdot}4^c$

Bismuth Trioxide.

Pulverized bismuth was burned in experiment 1. The trioxide was made by heating pure basic bismuth nitrate in a combustion tube to dull redness until acid fumes ceased to come off. A weighed portion of the oxide was found not to lose weight after fusion. The following are the experiments:

	1		3
Bismuth	20·000 gr.		
“ unburned..........	0·995 “		
“ burned	19·005 “		
“ trioxide		20·000 gr.	20·000 gr.
Sulphur	1·000 “	2·000 “	2·000 “
Water equivalent of system	3,935 “	4,256 “	4,005 “
Temperature interval.......	3·347°	3·445°	3·642°
Heat observed............	$13{,}170^c$	$14{,}662^c$	$14{,}586^c$
“ of oxidation of sulphur	$-5{,}271^c$	$-10{,}542^c$	$-10{,}542^c$
“ “ “ “ iron...	-48^c	-48^c	-48^c
“ “ oxygen set free	-60^c	-28^c	-48^c
	$7{,}791^c$	$4{,}044^c$	$3{,}948^c$
For 1 gram	410^c	202^c	197^c

In calculating the heat of formation of bismuth trioxide it makes no difference what sodium salt is formed in the fusion since the same one results from the action of sodium peroxide on both metallic bismuth and its trioxide. Moreover, assuming that a different peroxide is formed than Bi_2O_5 does not change the final result, since the heat effect of $Na_2O + O$ would vary by $19{,}400^c$ in both of the calculations below. From the mean of experiments 2 and 3 we have

$2Na_2O_2 + xNa_2O + Bi_2O_3 = (Na_2O)xBi^2O_5 +$ .... $92{\cdot}8^c$
$2Na_2O + 2O = 2Na_2O_2 +$ .... $38{\cdot}8$

$xNa_2O + Bi_2O_3 + 2O = (Na_2O)xBi_2O_5 +$ .... $131{\cdot}6^c$

From experiment 1 we have

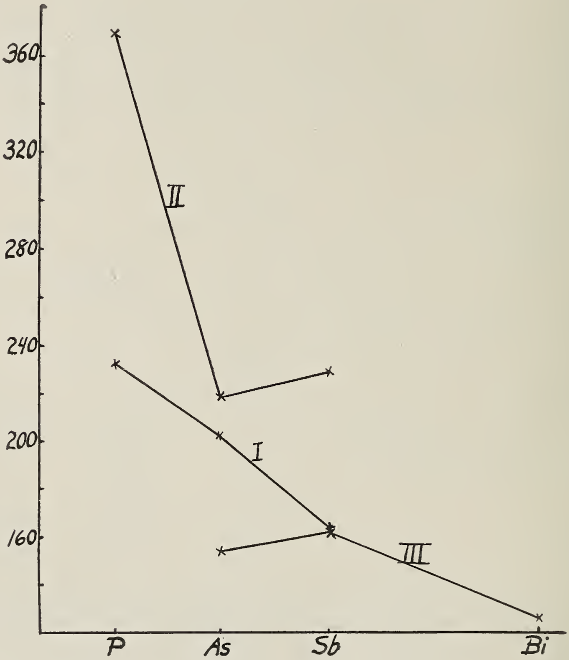
$5Na_2O_2 + 2Bi = (Na_2O)xBi_2O_5 + xNa_2O + \ldots\ldots\ldots$ 170·6
$Na_2O + 5O = 5Na_2O_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ 97·0

$xNa_2O + 2Bi + 5O = (Na_2O)xBi_2O_5 + \ldots\ldots\ldots\ldots$ 267·6

The heat of formation of Bi_2O_3 is $267·6^c - 131·6^c = 136·0$. This agrees well with Ditte and Metzner's* result of $137·8^c$.

The fusions of the calorimetric experiments left when treated with water a dull yellow product, which after drying

Fig. 1.



at 100° contained a peroxide of bismuth, water and a little sodium. It yielded on heating about half the weight of oxygen required to convert the Bi_2O_3 left into Bi_2O_5, that is, only about one-half of the bismuth in the substance was in bismuthic acid. Several preparations were made by heating a mixture of bismuth trioxide and sodium peroxide, and it was found that the bismuth compound formed gave off oxygen

* C. R., cxv, 1303.

slowly at room temperature and rapidly in hot water, retaining, however, considerable peroxide.

In the figure, atomic weights are plotted as abscissas and heats of combinations as ordinates. The line I shows the heat of the reaction $3Na_2O, R_2O_5$; II of R_2, O_5, and III of R_2, O_3.

We observe that, as the atomic weight of arsenic is nearly the mean of the atomic weights of phosphorus and antimony, so the heat of combination of arsenic pentoxide with sodium oxide is almost the mean of that of the union of phosphorus pentoxide and antimony pentoxide. The heat effect of $3Na_2O, R_2O_5$ is, therefore, closely related to the atomic weights of phosphorus, arsenic and antimony, and not to the affinity of these elements for oxygen. We also observe that the heat of oxidation of arsenic trioxide is nearly the same as that of antimony trioxide to the pentoxide.

Art. XIII.—*The Quantitative Precipitation of Tellurium Dioxide and its Application to the Separation of Tellurium from Selenium;* by Philip E. Browning and William R. Flint.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cci.]

All those processes for the estimation of tellurium in which the tellurium is precipitated and weighed in elementary condition are open to the objections that, first, there is more or less difficulty in securing completeness of precipitation owing to the rapid increase of free acid* in the solution; and, second, the product is extremely susceptible to oxidation. On the other hand, those methods in which compounds decomposable by heat are transformed to the dioxide by ignition are generally both tedious by reason of the length of time required (as for example, the basic nitrate process as described by Norris†) and, what is more to the point, liable to errors caused not only by lack of constancy of composition, but also by the volatilization of the product to be weighed.

Of all the forms in which tellurium has been weighed there is no doubt that the dioxide is the best. It is unaffected by the air, is anhydrous, is not hydroscopic, and can easily be obtained in pure condition. Likewise it can be heated to any temperature below low redness without any danger of volatilization. It was in view of these facts that some results obtained from an extensive study, about to be published, of the hydrolytic behavior of hydrochloric acid solutions of tellurium tetrachloride suggested the process about to be described.

When a tetrachloride solution containing the least possible excess of hydrochloric acid is sufficiently diluted with hot water, but a small portion, if any, of the tellurium is at first precipitated. By the addition of as little ammonia in excess as may be, and the restoration of the acidity by acetic acid in the faintest possible excess and then allowing the liquid to stand until cold, the tellurium is precipitated completely, as TeO_2, but in very finely crystalline condition. The precipitate is insoluble in cold water and alcohol, in acetic acid and ammonium acetate solutions of one per cent strength if cold, and filters, washes, and dries with the greatest facility.

In the first testing of the method, portions of pure dioxide were weighed out, dissolved in two cubic centimeters of concentrated hydrochloric acid, diluted with two hundred cubic centimeters of boiling water, and the ammonia, and subse-

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* Crane, Am. Chem. J., xxiii, 409. See also Lenher and Homburger, J. Am. Chem. Soc., xxx, 387.

† J. Am. Chem. Soc., xxviii, 1675.

quently acetic acid, added with great care. After standing over night, the liquid was decanted through the asbestos of a Gooch crucible, and the precipitate transferred and washed with cold water, and dried to constant weight at about 105°. In Table I, experiments 1 to 4, are gathered the results obtained.

TABLE I.

	TeO_2 taken grm.	TeO_2 found grm.	Error grm.
(1)	0·2002	0·2000	—0·0002
(2)	0·2019	0·2017	—0·0002
(3)	0·2904	0·2002	—0·0002
(4)	0·2006	0·2004	—0·0002
(5)	0·2011	0·2010	—0·0001
(6)	0·2003	0·2003	0·0000

In experiments 5 and 6, one and one-half cubic centimeters of ten per cent potassium hydroxide solution were used to dissolve the dioxide, instead of hydrochloric acid. The solution was then acidified slightly with hydrochloric acid, and the determinations completed from this point as before. The results seem to be equally good.

Next, weighed amounts of basic nitrate were dissolved in two cubic centimeters of hydrochloric acid. The small quantity of nitric acid holds up a little of the tellurium* and consequently before dilution resort was had to evaporation to remove as much of the free acid as possible. This had to be done with extreme care, since the least tendency on the part of the solution to boil was accompanied by the volatilization of the tetrachloride formed. With a not unreasonable amount of care, however, good results were obtained. In all of the experiments of Table II the dilution was with hot water, two hundred cubic centimeters being sufficient, but in several the treatment was varied, as given below.

TABLE II.

	$2TeO_2.HNO_3$ taken grm.	TeO_2 theory grm.	TeO_2 found grm.	Error grm.
(1)	0·2508	0·2094	0·2079	—0·0015
(2)	0·2501	0·2088	0·2086	—0·0002
(3)	0·2521	0·2105	0·2101	—0·0004
(4)	0·2500	0·2088	not completed	
(5)	0·2537	0·2118	0·2115	—0·0003
(6)	0·2510	0·2096	0·2091	—0·0005

* Gutbier, Studien über das Tellur, 46.

In experiment I, during the evaporation of the acid, there was noticed a slight volatilization of the tetrachloride, which accounts for the increased error. In 2, filtration was performed after twelve hours, and the same length of time elapsed in 5 and 6. Experiment 3 stood for two hours, and in this and number 4 potassium hydroxide was used in place of ammonia. So much tellurium was found in the filtrate from 4 that the determination was not completed. In 5 and 6, the basic nitrate was dissolved with two cubic centimeters of ten per cent potassium hydroxide solution, instead of the usual hydrochloric acid. Before dilution with hot water, hydrochloric acid was added in very slight excess. The ammonia added in number 6 was so much in excess as to dissolve completely the precipitate formed. The increased amount of ammonium acetate produced in the solution probably held up a trace of tellurium.

In order to observe the effects produced by variations in the factors concerned in the process, several experiments were performed, the figures for which are given in Table III.

Table III.

	$2TeO_2.HNO_3$ taken grm.	TeO_2 theory: Te taken as 127·5 grm.	TeO_2 found grm.	Error grm.
(1)	0·2502	0·2089	0·2083	−0·0006
(2)	0·2524	0·2108	0·2110	+0·0002
(3)	0·2505	0·2092	0·2089	−0·0003
(4)	0·2528	0·2111	0·2106	−0·0005
(5)	0·2531	0·2113	0·2106	−0·0007
(6)	0·5008	0·4182	0·4182	0·0000
(7)	0·5010	0·4183	0·4175	−0·0008
(8)	0·5005	0·4179	0·4178	−0·0001

The first four and the eighth were allowed to stand over night before the precipitate was removed; in the fifth one quarter hour, and in the sixth and seventh one half hour, elapsed. By a comparison of the results it appears that very little difference is made whether the time allowed to elapse be from 15 to 30 minutes or 12 or more hours, so long as the liquid is thoroughly cooled.

In all of the experiments of this series, the basic nitrate was dissolved with ten per cent potassium hydroxide solution, two cubic centimeters being sufficient in the first five, and four in the last three numbers. The solution in the case of the first two was then acidified slightly with hydrochloric acid, before dilution with hot water. In the rest, the alkaline solution was simply diluted with boiling water and faintly acidified with acetic acid, the precipitate being afterwards made crystalline* by further heating. It was noted that the precipitate formed by this variation of the method is not so quickly transformed to the crystalline condition as when the procedure of the experiments described in Table I is followed. It is, besides, still more finely divided and does not settle quite so well. There seems to be a distinct advantage in the use of ammonia, when added to the solution acidified with hydrochloric acid, since, if the diluted solution is sufficiently hot, the precipitate formed by the ammonia begins to become crystalline, apparently, at about the time when the point of neutrality is reached. Under these conditions, a few drops of dilute ammonia in excess have an inappreciable solvent effect upon the TeO_2 and consequently there is also no opportunity for the slight excess of acetic acid subsequently introduced to dissolve and thus hold up a trace of the tellurium. On the other hand, it seems probable that, when the acetic acid is introduced, in faint excess, into the hot, diluted solution, alkaline with potassium hydroxide, since the tellurium is precipitated in floccy form which does not become entirely crystalline until again heated, the excess of acid must dissolve up a more or less minute portion of the precipitate and retain it in solution in such a form as not to be again thrown down upon cooling. Two facts may be adduced in support of this theory, namely: first, that the errors in Table III show much greater irregularity than those of Table I; and second, that whereas the filtrates of I were shown by testing with stannous chloride to be free from tellurium, several of those in II, notably experiments 4, 5, and 7, were proved to contain it in traces.

And finally, the last three experiments of Table III show that it is perfectly possible to use quite as successfully one half gram of the basic nitrate, equivalent to four tenths gram of dioxide, in a single determination, employing a bulk of solution no greater than 200 to 250 cubic centimeters.

Attempts to separate tellurium from copper and bismuth by treatment with small amounts of potassium hydroxide solution, and to estimate the tellurium in the filtrate by this ammonia-acetic acid process, met with only moderate success. Under the conditions, the copper and bismuth apparently tend to form insoluble tellurites undecomposable by the allowable excess of alkali,† and consequently there was always a loss of tellurium. And further, if the bismuth or copper is precipitated together with the tellurium, it is practically impossible to dissolve out from the mixed precipitate all the tellurium by a hot

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* Berzelius, Ann. de Chim. et de Phys., 2 serie, lviii, 134 sq.

† Ibid., lviii, 114.

solution of the alkali. The results of two experiments with mixtures of bismuth and tellurium oxides are given in Table IV.

TABLE IV.

	TeO_2 taken grm.	Bi_2O_3 taken grm.	TeO_2 found grm.	Error grm.
(1)	0·2027	0·005	0·2015	−0·0012
(2)	0·2009	0·005	0·1997	−0·0012

In both cases, the mixed oxides were heated with two cubic centimeters of potassium hydroxide solution (10 per cent), the precipitate filtered out, and the filtrate diluted with hot water and precipitated by addition of acetic acid.

If hydrochloric acid solutions of tellurium and selenium dioxides be mixed, abundantly diluted with boiling hot water, and the operation of the above described process properly applied, only the tellurium is precipitated, the selenium remaining entirely in solution in the filtrate. This not only provides a simple and rapid preparative process for the purification of tellurium from selenium, but also makes possible the estimation of tellurium directly in the presence of the latter element.

TABLE V.

	TeO_2 taken grm.	SeO_2 taken grm.	TeO_2 found grm.	Error grm.
(1)	0·2015	0·2	0·2010	−0·0005
(2)	0·2013	0·1	0·1996	−0·0017
(3)	0·2003	0·1	0·1992	−0·0011
(4)	0·2009	0·1	0·2003	−0·0006
(5)	0·2000	0·1	0·2002	+0·0002
(6)	0·2015	0·1	0·2016	+0·0001
(7)	0·2038	0·1	0·2040	+0·0002
(8)	0·2028	0·05	0·2019	−0·0009
(9)	0·2024	0·05	0·2024	0·0000

Experiment 1 in Table V was made upon 0·2 grm. of TeO_2 in the presence of 0·2 grm. of SeO_3, which was later found to contain a little copper. After solution of the oxides in two cubic centimeters of hydrochloric acid and dilution to 200 cubic centimeters with hot water, precipitation was effected as usual by ammonia and acetic acid. Copper was carried down in the precipitate, as shown by its greenish color, the total weight after thorough drying being 0·2054 grm. In order to determine the amount of TeO_2 per cent, the precipitate was washed with ten per cent potassium hydroxide solution, the tellurium being carried away in solution as tellurite; the residue was washed with water until free from soluble matter, and dried to constant weight, yielding 0·0044 grm. The amount of TeO_2 by difference was consequently 0·2010 grm. But the residue, when dissolved in hydrochloric acid and tested with stannous chloride, showed the presence of a trace of tellurium.

In experiment 2, two cubic centimeters of the potassium hydroxide solution were used, and the hot, diluted solution acidified with acetic acid. In 3 and 4, after the solution in two cubic centimeters of potassium hydroxide, hydrochloric acid was added in faint excess, and the hot, diluted solution treated with ammonia and then acetic acid; the difference between these two determinations is apparently explained by the fact that in 3 the solution was allowed to cool a little before addition of ammonia, and thus the floccy precipitate was attacked by the acetic acid. In experiments 5, 6, and 7, potassium hydroxide was used to dissolve the oxides, hydrochloric acid was added to faint acidity, and the dilution made with cold water, which was then heated to boiling. It was evident that the floccy precipitation caused by the cold water included some selenium, which was not released by the change to crystalline form, since not only are the errors positive, but also the precipitate, when tested for selenium with potassium iodide by the delicate method of Norris, Fay, and Edgerly,* showed the presence of a trace of that element. In order to be certain that this is the true explanation of the fact, two more experiments, 8 and 9, were performed, in the first of which special care was taken to dilute with water actively boiling, and to carry out the subsequent operations as quickly as possible in order that the change of condition of the precipitate might occur before the acetic acid was introduced. No selenium could be detected in the precipitate of experiment 8. In the case of 9, the hot solution was allowed to cool somewhat before the precipitation, in consequence of which the abundant, floccy precipitate included a minute trace of selenium, as afterwards proved by the above mentioned test.

In order, therefore, to estimate tellurium as the dioxide by this method, it is evident that fairly accurate and concordant results can be obtained by dissolving the material in ten per cent potassium hydroxide solution, about two cubic centimeters for 0·2 grm. of dioxide, acidifying this solution slightly with hydrochloric acid, diluting to 200 cubic centimeters with boiling hot water, and precipitating the tellurium in a finely crystalline form of dioxide from the still hot solution by the careful addition of dilute ammonia in faint excess and the restoration of the acidity by the faintest possible excess of

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* Am. Chem. J., xxiii, 105.

acetic acid. If these simple operations are properly carried out, the precipitate will have become crystalline by the time when the excess of ammonia has been reached; the addition of a few drops of acetic acid will cause the precipitation to become entirely quantitative when the solution has cooled, so that no tellurium will be detectable in the filtrate by stannous chloride; the precipitate can be transferred, and safely and rapidly washed with cold water, and dried to constant weight at about 105° (or even up to just below low redness) in a quarter of an hour. Furthermore, the filtration can be performed at the end of half an hour or so, or after 12 to 24 hours, as most convenient. And, as shown by the experiments of Table V, selenium does not interfere, providing precautions are taken.

Art. XIV.—*Coloration in Peroxidized Titanium Solutions, with Special Reference to the Colorimetric Methods of Estimating Titanium and Fluorine*; by H. E. Merwin.

That the orange-colored solution obtained by treating titanium sulphate with hydrogen peroxide could be used in the determination of titanium was made known by Weller.* In the application of Weller's method to rock analysis Dunnington† found that in order to obtain results that were at all satisfactory the pyrosulphate melt usually employed as a means of rendering the titanium soluble must be dissolved in sulphuric acid of at least 5 per cent strength. Bailey and Dawson‡ concluded that the color of such titanium solutions is due to a soluble form of titanium trioxide. Hillebrand§ has pointed out that fluorine bleaches this color to a marked degree. Steiger‖ has applied this bleaching effect to the estimation of small amounts of fluorine. It is the purpose of this paper to show that large amounts of alkali sulphates have a bleaching action similar to fluorine, and further, that both rising temperature and addition of free acid intensify the colors thus bleached. Finally, methods of analysis taking account of these facts are described.

The following solutions were used in the experimental work: *Standard titanium solution* containing ·001 g. TiO_2 and about ·1 g. H_2SO_4 per 1^{cc}. This was made by gently heating an intimate mixture of 1 g. of TiO_2 and 3 g. of ammonium persulphate till the vigorous reaction had ceased, driving off the ammonium sulphate, treating the residue with 20^{cc} of strong sulphuric acid, heating to fuming and, when cold, pouring into about 800^{cc} of cold water.

The suspended titanium salt soon dissolved, after which $57·5^{cc}$ of strong sulphuric acid and water to make up to 1000^{cc} were added. If pure TiO_2 is at hand, this is a most expeditious method of obtaining a solution free from fluorine and notable amounts of alkali salts. The precaution of precipitating and weighing the TiO_2 in 50^{cc} or more of the solution should not be neglected.

Fluorine solution, containing ·001 g. of fluorine per 1^{cc}, made from recrystallized, washed, and strongly ignited sodium fluoride.

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* Ber. Deutsch chem. Gesell., vol. xv, p. 2593, 1882.

† Jour. Am. Chem. Soc., vol. xiii, p. 210, 1891.

‡ Studies from the Phys. and Chem. Laboratories of Owens Coll., vol. i, p. 216, 1893.

§ Jour. Am. Chem. Soc., vol. xvii, p. 718, 1895.

‖ Ibid., vol. xxx, p. 219, 1908.

Sulphuric acid 95-1/2 per cent, sp. g. 1·840.
Hydrogen peroxide of ordinary strength.

The standard colored solution was made from the above solutions. It contained 5^{cc} of the standard titanium solution, 2^{cc} of hydrogen peroxide and approximately $3·5^{cc}$ of sulphuric acid (including the free acid in the titanium solution), and was made up to 50^{cc}.

The test solutions each had the same volume as the standard, and contained the same amounts of titanium and hydrogen peroxide besides varying amounts of sulphuric acid, alkali sulphates and fluorine.

Methods of comparing the colored solutions.—During the early part of the work the comparisons were made by placing the test and standard solutions each in one of two parallel-sided glass containers of equal diameters placed side by side. The standard was then diluted to match the test. By this method the ratio of the coloring matter in the solutions is directly proportional to the final volumes of the solutions. Certain discrepancies appeared in the results of this method which were found to be due to a tendency on the part of the observer to overestimate the color in the left glass. The amount of overestimation varied considerably, but sometimes amounted to 6 per cent. For this reason all the later tests were made with Nessler tubes 6^{cm} long and $2·7^{cm}$ in diameter held over a white surface illuminated by diffused light. In making the comparisons the depths of the liquids in the tubes were so adjusted that when the tubes were changed right for left that the left one appeared uniformly darker. A close comparison could best be made by focusing the eyes on the surface six or eight inches in front of where the tubes were standing, and then lifting the tubes and bringing them momentarily within the field of vision. Solutions thus compared were first made up to equal volumes, then sufficient amounts of each were run into the Nessler tubes and the depths noted. Four to six comparisons were usually made for each set of solutions. The degree of coloration is inversely proportional to the depths of the liquids.

The temperature of the solutions was maintained at 21 1/2°–22 1/2° C. while they were being matched, except when the effects of temperature change were being investigated.

Agents Affecting the Coloration of Peroxidized Titanium Solutions.

Free acids.—Colored titanium solutions that have been bleached have their color restored as the acidity of the solution is increased. Sulphuric, nitric, and hydrochloric acids, and probably others, produce similar effects. The amount of the effect in the case of sulphuric acid is shown in detail further on in the paper, in connection with studies of the bleaching agents.

Temperature.—In solutions containing no bleaching agents changes of temperature of 50° C. intensify the color 5 to 15 per cent. In the presence of bleaching agents the color is intensified by heating. In certain instances heating 10° C. restores 30 per cent of the color lost by bleaching. (See fig. 1, C.)

Alkali sulphates.—The sulphate solutions used for the tests were prepared chiefly from six lots of Baker's analyzed reagents. Sixteen samples of sodium, potassium, and ammonium carbonates, sulphates and bisulphates were employed. Several of the samples were converted into pyrosulphates before testing in order to expel any possible volatile impurity that might bleach the titanium solution. However, such treatment had but little effect. Definite amounts of sulphates and of acid were introduced into test solutions and the amount of bleaching determined. The bleaching produced by equal molecular proportions of the sulphates appears to be equal. The amount of bleaching for potassium sulphate is indicated approximately by the following table of averages from the tests:*

Sulphate grams	Acid cc.	Bleaching per cent
3	·5	15
	2·	9
	8·	2
6	·5	21
	2·	14
	8·	5

Fluorine.—The percentage amounts of decoloration by fluorine in test solutions of known acidity at 22° C. are shown in fig. 1, B. For example, in a test solution containing $3·5^{cc}$ of strong sulphuric acid, ·0019 g. of fluorine causes a bleaching of 30 per cent. The depth of the color of the solution is then 70 per cent of the original. Upon heating, the color is restored as shown in fig. 1, C, G. At 70° C. the color is only 6 per cent less deep than in a standard solution at 22° C.

Various compounds.—The effects produced by the compounds mentioned in this paragraph are given as determined by Steiger and as verified or modified by the present experiments. Aluminium sulphate has no marked effect on standard solutions or on solutions bleached by alkali sulphates, but it

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* At least part of the bleaching in faintly acid solutions, attributed by Dunnington to metatitanic acid, was due to alkali sulphates. Steiger concluded that alkali sulphates have little effect upon the color of solutions bleached by fluorine. The probable slight excess of acid in his sulphate solutions would account for his results.

restores the color to a considerable degree to solutions bleached by fluorine. Ferric sulphate produces effects similar to aluminium sulphate, and also modifies the color because of the color of its own solution. Phosphoric acid bleaches a standard solution. Silica to the amount of ·1 g. introduced in the form of soluble sodium silicate into solutions considerably bleached by fluorine, produced no more effect than could be accounted for by the sodium sulphate generated.

Doubtless there are many other substances that alter the color of peroxidized titanium solutions, but the ones here considered are the only ones ordinarily encountered in notable amounts in solutions that would be used for the colorimetric estimation of titanium or fluorine.

Application to analytical processes.—In the estimation of titanium by Weller's colorimetric method a correction must be made for the effect of alkali salts, if such salts are present in considerable quantity. The acidity of the solution must be considered also. The above table shows the magnitude of the corrections necessary for solutions containing ·005 TiO_2, and the amounts of free acid and of normal alkali sulphate indicated. For example, 20 per cent too little, that is ·004 g., of TiO_2 would be found in such a solution containing 6 g. of alkali sulphate and 6^{cc} total free acid.

For amounts of TiO_2 more or less than ·005 g., these corrections will not hold. Twice this amount would require about half the correction, and half this amount twice the correction. Inasmuch as the correction can be made smaller by increasing the acidity of the solution, it is highly desirable to do this. *In rock analysis* by using 6 g. of pyrosulphate, which is equivalent to 4 g. of normal sulphate and 2 g. of acid, for the melt containing the titanium, and dissolving this in water to which 10^{cc} of strong sulphuric acid has been added, a nearly negligible correction of only 3 per cent need be added. If the TiO_2 exceeds ·02 g. no correction is required. In case the melt is dissolved in 100^{cc} of 5 per cent sulphuric acid, the titanium found—if the amount is between ·002 g. and ·01 g.—is too low by approximately ·0004 g.*

Estimation of Fluorine.—During the progress of this study it was found that when the Nessler tube method was used, the percentage ratios obtained by dividing the depth of each solution bleached by fluorine by the depth of its matched standard, could be plotted in lines so nearly straight that from the lines simple formulas could be derived for use in analysis.†

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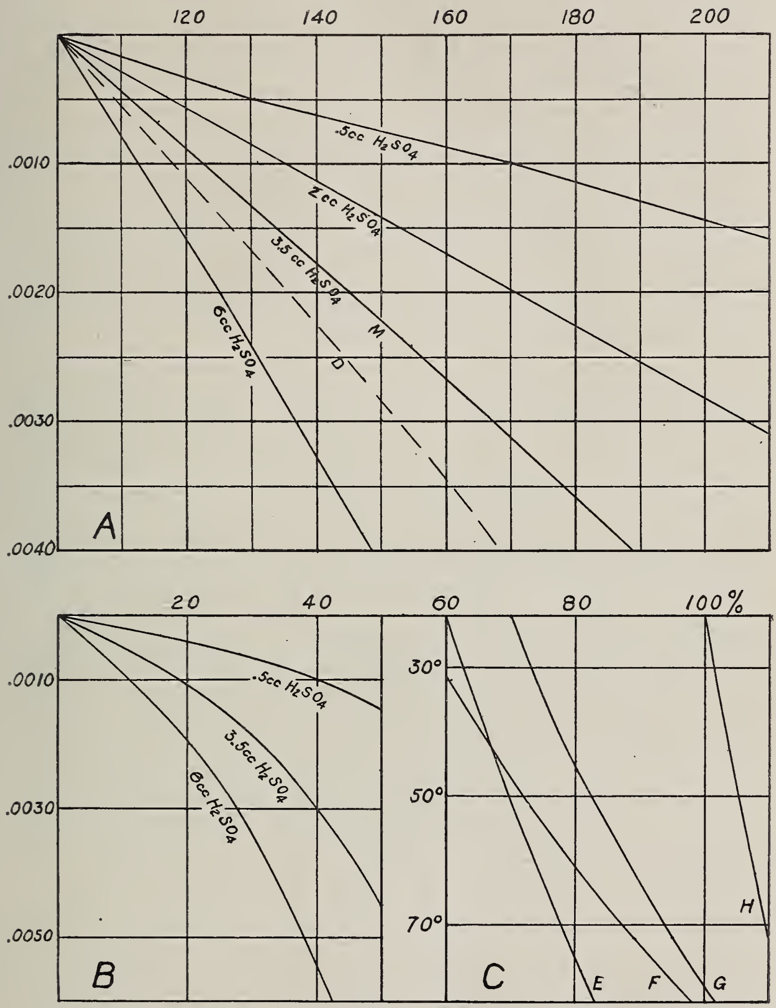
* It seems safe to conclude that the amounts of titanium in igneous rocks, estimated colorimetrically, have fallen short by nearly this amount in a 1-gram sample, for as much as 10 grams of pyrosulphate have often been used, and probably seldom more than 200^{cc} of dilute acid.

† The same ratios are obtained by dividing the final volume of the standard by the volume of the test in cases in which a colorimeter is used which requires the standard to be diluted.

FIG. 1.



A. Coloration in peroxidized titanium solutions in presence of fluorine and free sulphuric acid. The fluorine in grams is read on the ordinate. The percentage ratios of depths of color in the standard solution to depths of color in the test solutions are read on the abscissa. For given amounts of fluorine and acid the ratio is found above the intersection of the lines representing the fluorine and acid. The curves are plotted for a temperature of 22° C. The line M migrates to D as the solution is heated to 32° C.

B. The percentage of bleaching by fluorine may be found from these curves in the same way that the coloration ratios were found from the curves of A.

C. Showing the rise in percentage of coloration due to heating. Curve E for a solution containing 1^{cc} of sulphuric acid and ·0014 g. of fluorine; F for $3·5^{cc}$ of acid and ·0037 g. of fluorine; G for $3·5^{cc}$ of acid and ·0019 g. of fluorine; H for a solution standard at 22° C.

The full lines of fig. 1, A were thus plotted. Suppose this ratio r in a particular case is 142, and that there is ·5^{cc} of acid in the test solution, then the corresponding amount of fluorine is ·0006 g. The formula expressing this relation is $\frac{r-100}{70,000}$ = g. of fluorine. With 3·5^{cc} of acid in the test solution the formula is $\frac{r-100}{22,000}$ = g. of fluorine. By the conditions of the first formula amounts of fluorine between ·00005 g. and ·001 g. can be estimated accurately within ·00005 of a gram; by the last formula amounts between ·001 g. and ·004 g. can be estimated within ·00015 of a gram. By doubling the amounts of titanium and acid in the test solution and making it up to 100^{cc}, ·01 g. of fluorine can be estimated.

The above formulas can not be used in rock analysis because of the disturbing effects of the alkali sulphates necessarily present in the test solution. In order to make it possible to know accurately the composition of the solution in which fluorine is to be determined in rock analysis, the following method has been worked out.

Two grams of the rock powder are fused with 8 grams of mixed sodium and potassium carbonates and the fusion is taken up with hot water. When leached, and without the necessity for filtering, there are added 3 or 4 grams of powdered ammonium carbonate; the mixture is warmed for a few minutes, and then heated on the water bath till the ammonium carbonate is destroyed, and the bulk of the liquid is small. In this way the silica, which otherwise might render the final solution turbid, is thrown down together with the disturbing alumina and ferric oxide. The destruction of the ammonium carbonate is necessary because ammonium sulphate bleaches the final solution. After filtering there is added to the filtrate—which should not exceed 75^{cc} in volume—3 or 4^{cc} of hydrogen peroxide, and then cautiously 10^{cc} of standard titanium solution* (containing ·01 g. TiO_2). Including the acid in the titanium solution, about 4^{cc} of strong sulphuric acid are required to neutralize the alkali carbonates. As soon as neutrality is reached the solution acquires a light orange color. Neutrality is tested by adding a little sodium carbonate solution to discharge the color, and then a drop or two of acid to restore it. The further treatment depends upon the amount of fluorine expected. In the vast majority of cases this amount is less than ·0025 g. (·125 per cent of the sample). For such amounts there is added to the neutralized solution 3^{cc} of concentrated sulphuric acid, and the solution is made up to 100^{cc}. After being cooled

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* The hydrogen peroxide prevents the precipitation of the titanium by the alkali carbonate.

to 22° C. the solution is compared with a 100^{cc} solution containing ·01 g. of TiO_2, 4^{cc} of H_2O_2 and 2 or 3^{cc} of concentrated sulphuric acid. The ratio, r, of depths (or volumes) of the solutions is obtained as described in the preceding section. This ratio is, however, much larger than the fluorine would give, owing to the alkali sulphates. The ratio that the alkali sulphates alone would give, if free from interfering substances, is about 125. Different samples never give quite the same ratio. Those that give a ratio much higher than 125 probably contain fluorine. The safest way is to make determinations of this ratio on two 8-gram portions of the carbonates used in the fluorine estimation,* and to use this ratio in making the correction. Having obtained this ratio—call it m—the formula for computing the fluorine is: $\frac{r-m}{23{,}000}$ = grams of fluorine. Accuracy to one ·0002 of a gram may be expected. The probable error is therefore not half as great as with the standard gravimetric methods.†

If the fluorine expected amounts to ·0025 to ·0120 grams, the test solution is made acid with 12^{cc} of concentrated sulphuric acid, and compared as before described. The formula is $\frac{r-m-3}{6{,}300}$ = grams of fluorine: m is to be determined and should not much exceed 108. Accuracy to ·0005 g. may be expected.

Thanks are due to Professors J. E. Wolff and T. W. Richards for suggestions and criticism.

Petrographical Laboratory, Harvard University, May, 1909.

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* The 8 grams of carbonates dissolved in about 75^{cc} of water are treated precisely like the filtered fluorine solution.

† Hillebrand, W. F., The Analysis of Silicate and Carbonate Rocks: Bull. U. S. Geol. Survey, No. 305, p. 158, 1907.

ART. XV.—*New Fossil Coleoptera from Florissant;* by H. F. WICKHAM.

Calosoma Web.

C. calvini n. sp. Represented by a well preserved elytron, measuring 16·30^{mm} from the humeral angle to the apex of the specimen, the extreme point and a portion of the scutellar region being lost. Greatest width (about apical two thirds) 5·90^{mm}. The sides are approximately parallel, only slightly broadening from the base to that point, the outer margin thence regularly arcuate to the tip. The margin is quite broadly reflexed at the humerus but becomes narrower posteriorly, and fades out about the broadest part of the elytron. Surface with about eighteen striæ, well impressed and sub-equidistant, the two exterior somewhat indistinct for about half their length at base and apex. The fifth stria joins the fourteenth at a point about 2^{mm} from the apex, forming an arc within which all the enclosed striæ come to an end, while those outside continue nearly or quite to the tip. Interstices rather faintly but distinctly convex, divided by fine transverse lines into quadrate spaces which are broader than long; striæ plainly and fairly deeply punctured, the punctures small and distant, distinct to the extreme apex.

This specimen indicates a species considerably larger than *C. emmonsi* Scudder, which was also described from the Florissant shales, and differs as well in having distinctly punctured elytral striæ. The general arrangement of the striæ near the tip is less like that of the recent *C. wilcoxi* (with which Scudder compares his *C. emmonsi*) than of our common *C. calidum*, but the foveæ, which can be made out on the fourth, eighth and twelfth interspaces, were apparently small as in *C. wilcoxi*.

The type, described above, is without exact indication of locality, being marked simply Florissant, 1908. It was received from Prof. Cockerell. A second specimen, collected by Mrs. Cockerell at Station 13, is also referred to this species. It consists of an elytron in much less perfect preservation than the type and portions of two legs, one of which, though actually smaller, shows the tarsal joints to have been proportioned almost exactly as in *C. scrutator*. The elytron is somewhat smaller than the type, measuring about 14^{mm}, but as far as can be seen is similarly punctured.

I take pleasure in giving to this fine species the name of my honored instructor and colleague, Dr. Samuel Calvin, as a slight recognition of his worth as a man and a geologist.

The holotype is in Peabody Museum of Yale University. Cat. No. 4.

Acilius Leach.

A. florissantensis n. sp. The specimen shows an underside in only fair preservation, the two hind legs in place and what appears to be one of the patellate front tarsi, indicating that the insect was a male. The species is about the size and shape of our common *A. semisulcatus* but apparently with slightly longer tibæ and with the second abdominal segment somewhat shorter in proportion to the third. Length 13^{mm}, width $9{\cdot}25^{mm}$.

Station number 14. Collection number 257. Received from Prof. Cockerell. Holotype in Peabody Museum of Yale University. Cat. No. 5.

No other species of this genus has been reported from the Florissant shales, and while the specimen in hand is not sufficiently perfect to show many truly specific features, it seems worth while to characterize it as well as possible, since the generic facies is quite well marked and so few fossil aquatic adephagous beetles are known. The genus is represented in North America by only three species, two of which are very closely related.

Philydrus Sol.

P. scudderi n. sp. Almost regularly oblong-elliptical, elongate, evenly and slightly narrowed at each end. Head large, $1{\cdot}35^{mm}$ wide and ${\cdot}70^{mm}$ long, eyes not defined, antennæ and palpi lacking, except the pseudo-basal joint of one of the latter which is too indistinct for study. Prothorax short, broadest just perceptibly in front of the base, sides regularly and slightly curved to the apex, front angles damaged, apical margin roundly emarginate, base subtruncate at middle, slightly sinuate each side, finely margined, hind angles apparently slightly less than right and somewhat rounded. Sides of elytra nearly straight to about the middle, thence gradually regularly rounded to the apex. Sutural margin with very fine bead. Legs not shown. Scutellum rather small. Length $5{\cdot}25^{mm}$, width $2{\cdot}65^{mm}$.

The surface of this specimen shows a scabrous granulation which is probably due, in part at least, to the decomposition of the exoskeleton. It is, however, sufficiently well preserved to show that the insect was black. On the sides of the prothorax are some coarse punctures recalling the similar group in *Hydrobius fuscipes*.

The specimen almost exactly resembles the description and figure of *Tropisternus limitatus* Scudder, also from the Florissant field. I should have placed it there had not Dr.

Scudder definitely stated that no sculpture whatever (except certain raised lines) was shown in his examples. Further, the entire facies of my specimen and particularly the small size of the scutellum lead me to place it in *Philydrus* rather than in *Tropisternus.* It is, of course, impracticable to carry the identification into the groups (based upon palpal characters) created by the dismemberment of the old genus *Philydrus.*

Station number not given. Collection number 51. Received from Prof. Cockerell. Holotype in Peabody Museum of Yale University. Cat. No. 6.

Podabrus Westw.

P. wheeleri n. sp. The type specimen, consisting of obverse and reverse, shows one elytron entire and a part of the other, the head, thorax and abdomen, one leg of each pair and both antennæ. Parts of the remaining legs are visible through the overlying parts of the body.

Head moderate, eyes small, apparently about as in *Chauliognathus pennsylvanicus.* Antennæ seemingly eleven-jointed, moderately slender, the first joint larger, second apparently about one half as long as the third, the fourth and following considerably longer, all the joints, especially the proximal ones, noticeably broader at apex. Prothorax apparently not greatly differing in width from the head, broader than long, truncate in front. Elytron subtruncate at tip, the disk finely costulate (probably twice). Abdomen projecting beyond the elytra the length of two visible segments; another may have been broken off. Legs moderately stout for this family, the hind ones much longer than the others. Tarsi all partially mutilated, so that it is impracticable to describe individual joints, but the tarsus of the middle leg seems to be of the type shown in the recent *Podabrus comes.* The basal joint of this tarsus seems to have been displaced. Length of specimen entire 17·25^{mm}, of elytron 11^{mm}, of antenna 7·50^{mm}, of hind femur 5^{mm}, of hind tibia 5^{mm}.

Station number 13. Collection number 165. Received from Prof. Cockerell.

A long study of this insect has resulted in maintaining it in the position given it at first sight. The length of the abdomen is probably due in part to maceration before the embedding was completed. The antennæ are essentially of a Podabroid type, and I think the generic assignment is not far out of place. As will be seen from the measurements, the size is considerably above the average of the American species of *Podabrus*, but this is largely due to what I consider the unnatural extension of the abdomen. Nothing allied is known from the Florissant shales. The fact that the specimen is preserved principally in side profile accounts for the lack of comparative measurements of the prothoracic proportions in the foregoing description.

Named for Dr. W. M. Wheeler, who has figured the type as an undescribed Meloid in the American Museum Journal, vol. vi, p. 202.

Holotype in Peabody Museum of Yale University. Cat. No. 7.

Trox Fabr.

T. antiquus n. sp. Form oblong, broader behind, widest about one third before the apex of the elytra. Head concealed. Prothorax slightly less than twice as wide as long, broadest at or very close to the base; sides regularly arcuately narrowing to apex, which is much narrower than the base; surface finely, fairly regularly granular, uneven. Base arcuately emarginate each side for the reception of the elytra, each of which is ornamented with about eight rows of small granular tubercles, general surface uneven. There appears to have been a large tubercle on each side of the suture about one fifth from the base, but this may be fortuitous. Length 5·75^{mm}, width 3·25^{mm}.

Station 14, Mrs. Cockerell. Collection number 274, Florissant Expedition 1906.

This species seems to have been about the size of a rather small specimen of the recent *T. æqualis*, but with sculpture more resembling *T. atrox*.

Type in the British Museum of Natural History.

Meracantha Kirby.

M. lacustris n. sp. A profile is shown in fair preservation exhibiting head, thorax, elytra and three legs, apparently the hind pair and one of the middle. Head small, antennæ wanting except what may be the basal joint of one. This joint is quite large and broad, but I believed it to be crushed. The only palpus showing has the last joint distinctly triangular. Prothorax longitudinally very convex, posterior margin straight when viewed from the side. Elytra also strongly longitudinally convex. Legs very long and slender, thighs strongly clavate towards the tip, tarsi obscure. Length 10·50^{mm}, elytron 7·50^{mm}, hind femur 4·75^{mm}, hind tibia 4^{mm}.

Station number 11. Collection number 222. Received from Prof. Cockerell. Holotype in the Peabody Museum of Yale University. Cat. No. 8.

I am not able to decide definitely as to the probable nature of the sculpture in this specimen. So much variation exists in the fineness of the different layers of shale that it is frequently hard to tell characters due to the insect from those dependent on the matrix. However there is an appearance of distant impressed lines or striæ on the elytra.

The generic reference, naturally, is only provisional; more perfect specimens may throw the insect in some other genus. The outline, however, is strikingly like our recent *Meracantha contracta*, but the fossil is considerably smaller and has more slender femora which are more strongly and suddenly clavate towards the tip.

Mordella Linn.

M. lapidicola n. sp. A species about the size of our recent *M. scutellaris* showing the characteristic wedge-shaped form, long hind legs and anal style of *Mordella* and its allies. The specimen exhibits a side view in obverse and reverse. Three legs are visible, one of them belonging to the posterior pair. Antennæ and mouthparts are obscured, and as the slab of stone in which the specimen is preserved is of coarse texture the sculpture is obliterated. Probably the insect can be distinguished from any others which may be discovered in these shales by the comparative measurements. Length 6·75^{mm}, anal style, beyond elytral tip, 1·75^{mm}, hind femur 1·30^{mm}, hind tibia ·90^{mm}, hind tarsus 1·75^{mm}, first joint of this tarsus ·75^{mm}.

Station number R. 13 B. 1908. Received from Prof. Cockerell. Holotype in Peabody Museum of Yale University. Cat. No. 9.

Iowa City, Iowa.

ART. XVI.—*On the Lighthouse Granite near New Haven, Connecticut;* by FREEMAN WARD.

Introductory Note.—The Branford granite-gneiss has heretofore been considered a single unit of like character throughout.* While in a general way this is true, yet, from a closer investigation in both the field and laboratory, it has seemed reasonable to make a separation of the mass into two types—the Branford granite and the Lighthouse granite. The differences between them, while not great, are yet thoroughly constant. It is proposed in this paper to consider the latter of the two types.

LOCATION AND TOPOGRAPHY.

The formation in question is situated on the coast of Long Island Sound, near New Haven, Conn. Lighthouse Point, on the east side of New Haven Harbor, is its most westerly point. From there it extends east to Branford Harbor (four miles in a straight line). In width (north and south) it varies from a half mile to over a mile and a half. The accompanying map (fig. 1) will show its position and extent. On the north it is bounded by the Triassic formation: the contact line between them starts at the south part of Morris Cove, passes east and a little north to the south end of Beacon Hill; from there it extends northeast towards a point on the Shore Line division of the New York, New Haven and Hartford railroad, about a half mile west of the Branford station. On the east it meets the Branford granite; the contact between them passes up through Branford Harbor, keeping about a quarter of a mile west of Branford Point till it reaches just beyond the trolley tracks, then passes northwest to the Triassic. On the south and west the formation passes into the Sound and New Haven Harbor respectively.

The topography is not striking, that is, there is little relief; the highest point in the formation has an elevation of only 120 feet, and fully one half has an elevation of 20 feet or less above the sea. There are many marshy areas, which are for the greater part flooded by a few inches of water at high tide. The shore line is quite irregular with many small bays, inlets, points, peninsulas and off-shore islands: one large bay opens off of Short Beach. The shore from Lighthouse Point to Mansfield's Grove is made up in a broad way of a series of arcs convex inland. The greater part of the shore has well-exposed

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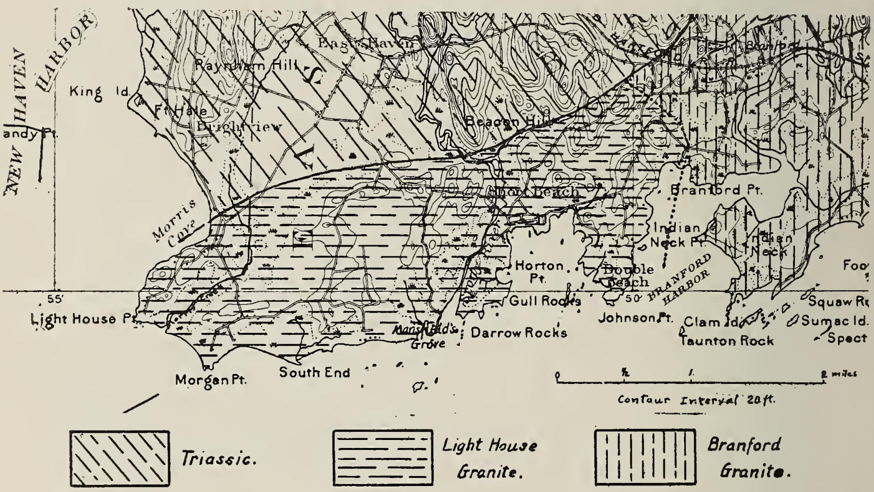
* W. N. Rice and H. E. Gregory, Manual of the Geology of Connecticut; Conn. State Geol. Nat. Hist. Surv., Bull. No. 6, 146, 147, 1908.

ledges: sandy beaches are not common except in the western portion. Inland, between the areas of salt marsh, the low hills have the smooth, rounded outlines commonly seen in this glaciated region: they are usually well wooded, and the slight depressions between them are freely sprinkled with fresh-water swamps. These hills show numerous outcrops. Four or five small quarry openings and a few open cuts along the trolley lines afford an opportunity of seeing the rock below the surface.

HISTORICAL.

The region has been known geologically in a broad way from very early times. The first geological map of the eastern United States* has Connecticut colored in with "Primary" and "Secondary" rocks, referring to crystallines and Triassic respectively. In the nature of the case there could be no specific description of any part of the crystallines.

FIG. 1.



E. Hitchcock,† in a description of the formations on each side of the Connecticut river from Vermont to the Sound, makes a separation of the granites from the other rocks, but maps all the granites from Lighthouse Point to Guilford as one formation.

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* W. Maclure, Amer. Phil. Soc. Trans., vi, p. 411, and map, 1809.

† This Journal (1), vi, 1823.

J. G. Percival, in the best map of Connecticut up to 1906* under a description of the Primary rocks, subdivision A1a, separates the Lighthouse–Branford granite from the Stony Creek granite farther east. He notes the pink feldspar and the gneissic character of the rock in places. While his observations and mapping were remarkably accurate for his time, yet the state of geologic science at that period did not permit any more definite or scientific delineation of the formation.

J. D. Dana mentions† a "granite or granite-like gneiss" on Lighthouse Point, but gives no detail of description of the formation or its extent.

There have been other references to the region by the older geologists, but only in the more or less vague terms "primary", "granite", "gneiss", "metamorphics", crystallines", etc.; no special descriptions are given and the value of such articles is practically only historical.

The most complete geological map of Connecticut to-day is that published by the State Survey.‡ This, with further description in the Manual of the Geology of Connecticut,§ brings the knowledge of the region up to date. The Lighthouse granite is here included under the Branford granite-gneiss as one formation. Only a brief outline of the main characters of the mass are given. The authors state that sufficient data have not yet been accumulated on which to base a complete description of this rock.

FIELD GEOLOGY.

General.—The formation as a whole consists of a medium-grained granite of pink or reddish color. The structure may be gneissic, varying from that well-developed and easily seen in the hand specimen to that which only shows in the mass. The average hand specimen would not show a well-marked gneissic structure. It meets the Triassic sandstones, shales and traps abruptly, the contact throughout being a fault contact. It grades imperceptibly into the neighboring Branford granite.

The uniform character of the granite of this formation is modified by several features, viz.—pegmatite, aplite, quartz veins, inclusions, as well as some variation along the fault contact. These modifications will be noted in detail, as follows:

Pegmatite.—Pegmatite is very common throughout the area. In general appearance it may be described briefly as a

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* Report on the Geology of the State of Connecticut, 1842.

† The Four Rocks, with Walks and Drives about New Haven, 1891, p. 89.

‡ H. E. Gregory and H. H. Robinson, Preliminary Geological Map of Connecticut, State Geol. Nat. Hist. Surv., Bull. 7.

§ W. N. Rice and H. E. Gregory, State Geol. Nat. Hist. Surv., Bull. 6, pp. 146–147.

very coarse granite. It has two habits of occurrence—(1) True dikes having definite directions and with well-defined boundaries. But the contact with the normal granite is never sharp and clear-cut; at a little distance it may seem to be so, but on closer inspection the pegmatite and granite proper are found to merge one into the other within a distance of half an inch. These dikes vary in width from less than an inch up to as much as ten feet, but six or eight inches is a more common width. They vary in length from ten or fifteen yards to a hundred or more. They may be parallel with the gneiss planes or cut across them in any direction; occasionally their course is the same as the neighboring joints. In some cases the smaller dikes are lens-like, thinning out within a few yards; this kind is apt to have its center portion made up of quartz alone, changing gradually to the normal quartz-feldspar mixture as its margin is approached. (2) A large portion of the pegmatite occurs in irregular patches and smears scattered through the granite. They do not extend in definite directions; nor do they have well-defined boundaries, but grade into the surrounding rock. Their size varies from that of one's hand to those several square yards in extent; or there may be quite large areas which are a heterogeneous mixture of pegmatite and granite. This patchy type of pegmatite can be considered as an intermediate stage between true pegmatite dikes and true miarolitic cavities. The latter, as is well known, are characterized by irregularity of boundary and direction, and only differ from the irregular pegmatite of the area in having cavities in their middle portions. There is no difficulty in distinguishing the patchy pegmatite from the miarolitic type; the relation between them can easily be seen and gradations between the two can well be imagined. No true miarolitic cavities have been found in the granite.

The two types—definite dikes and irregular, ill-defined patches—suggest two periods of pegmatization; one occurring while the granitic magma was unconsolidated and in a pasty condition, another occurring when the magma was all but solidified into rock, the latter period of course being the time when the dike type of pegmatite was formed.

Aplite.—This type of rock is less common than the pegmatite. Its occurrence is of two kinds—as in the case of the other—dikes and irregular streaks. It has the usual fine-grained, sugary texture. It is simply a finer grained granite with less ferro-magnesian minerals than normal granite. The ferro-magnesian minerals may fail utterly at times. The texture also may be rather coarse occasionally.

Quartz-veins.—These are common throughout the whole area. Usually they are small, a few feet to a few yards long, and from a fraction of an inch to six or eight inches in width. They may cut the rock in any direction, but in a few cases are found to have a trend parallel to the joints of the locality. At several points these veins are large, that is are measured by yards rather than by feet or inches.

Inclusions.—In places and spots throughout this granite occurs a material which is different from the normal granite or pegmatite. It is a well-banded gneiss and may best be described as a biotite-gneiss injected with granitic magma. The injection varies from thin lines of pinkish granite material to broad (half-inch) layers of distinct granite. The granitic magma has entered the gneiss along its natural structure planes for the most part, accentuating the original gneissic structure, but sometimes has cut across the whole in any direction. The development of large orthoclase crystals has bent the planes of the gneiss out of alignment; these large feldspars give the rock in some places a porphyritic appearance Most of the specimens are over fifty per cent granitic magma, but, on the other hand, some of them are apparently not injected at all. In shape they may be slab-like, or they may occur in small pieces or large blocks. They vary in size from a few inches to several yards in diameter. Their outlines, while distinct, are not sharp.

This gneiss is an older rock as is shown by the fact that it occurs as irregular masses or blocks included in the normal granite, and also by the fact that in places the injections of magma can be followed back into the enclosing granite. It is believed that these included masses are modified fragments of the country rock into which the granite mass as a whole was intruded; they resemble very closely the Middletown gneiss, which occurs in place several miles to the northeast.

The inclusions occur very sparingly in the western half of the Lighthouse granite and are not abundant, on the whole, even in the eastern part. They are seen well at Mansfield's Grove, also at a point upwards of a half mile north of the Grove along the road.

Contact Phase—There are a few places at or near the contact with the Triassic where the rock has an appearance different from that already described. In the first case the rock is denser and has a greenish material (chloritic) scattered through it in streaks and smears or occurring in thin dike-like planes following the joint directions. Secondly, the rock may be quite broken in appearance, due to the presence of many sets of intersecting joints, and may approach the character of a true breccia. Or lastly the rock may be whitened or bleached—the result of greater alteration along a fractured zone.

Since the above phenomena are largely the result of dynamic action, they may occur along any fault or fracture zone in this mass.

PETROGRAPHY.

The Main Granite—Megascopically the rock is seen to be a typical granite, i.e., it is composed chiefly of feldspar and quartz and has a granular texture. The feldspar is of two kinds, pink and white, with the pink predominating, and, as usual where the two kinds thus appear together, the pink is orthoclase and the white albite. The quartz is commonly gray and glassy, but in weathered specimens may be coated with a yellowish hydrated oxide of iron.

Of the accessory minerals biotite is the most noticeable but it is by no means abundant: it usually occurs as scattered flakes evenly distributed, but occasionally it may be seen in smeary segregations or "schlieren." Muscovite appears sparingly; is more common near Lighthouse Point and in general near the fault contact. Magnetite, though not appearing in every hand specimen, can be said to be a common accessory in a broad way. Garnets have nowhere been encountered: a negative statement of this kind is only of value when the rock is compared with the Branford granite. The texture is quite uniformly medium-grained; there are local exceptions to this general rule.

Under the microscope the rock is also seen to be a simple granite as far as mineral content goes. The minerals present are,—orthoclase, microcline, plagioclase, quartz, biotite, muscovite, sericite, chlorite, magnetite, zircon, apatite, (calcite).

The orthoclase greatly predominates over the other feldspars and presents nothing unusual. Microcline is not present in any great amount; it shows the usual basket structure. The plagioclase is practically all albite, only a little oligoclase being present.

The quartz is characterized uniformly by an undulating and broken extinction. In some instances it is so broken as to be granulated. The graphic arrangement of quartz in feldspar occurs in a few cases.

An occasional flake of muscovite appears in the slides, but most of the white mica is present as fine scales of sericite scattered through the feldspars or somewhat segregated in cracks in those minerals.

Biotite appears as the usual brownish, pleochroic flakes. It may be partially or entirely altered to chlorite. Chlorite when present is only a product of alteration of the biotite.

Calcite is seen only in those specimens which have been weathered considerably. Magnetite, zircon and apatite occur in small amounts with no unusual characters; the quantity of the latter is small even for an accessory mineral.

Chemical Composition.—The chemical composition of this granite is given below in column I: the other analyses are inserted for comparison:

	I	II	III	IV	V
SiO_2	72·47	72·47	73·05	71·23	73·93
Al_2O_3	14·73	14·78	14·53	13·64	12·29
Fe_2O_3	·96	·57	2·96	1·70	2·91
FeO	·97	2·00		1·00	1·55
MgO	Tr.	·34	Tr.	·75	·04
CaO	·81	1·27	2·06	2·31	·31
K_2O	5·61	4·53	5·39	3·79	4·63
Na_2O	3·69	4·03	1·72	3·55	4·66
P_2O_5	·04	Tr.	—	—	—
H_2O	·72	·48	·29	1·72	·41
CO_2	·10	Tr.	—	·05	—
TiO_2	N.D.	N.D.	—	·21	·18
	100·10	100·47	100·00	99·95	100·91

I.—Lighthouse Granite, anal. F. Ward.
II.—Branford Granite, anal. F. Ward.
III.—Westerly (red) Granite, anal. F. W. Love; used by J. F. Kemp, Bull. Geol. Soc. Amer., x, 375.
IV.—Conanicut Granite, anal. L. V. Pirsson, this Journal, xlvi, 373, 1893.
V.—Quincy Granite, anal. H. S. Washington, this Journal, vi, 181, 1898.

The rock belongs decidedly to the alkalic group of granites, as is shown by the small amount of R″ elements, particularly lime, and the high alkali content. It is noticeable that the potash is greatly in excess of the soda.

Alteration.—This, while appearing in all specimens to some degree, is not extensive: none of the ledges is so far weathered, for instance, as to show any residual soil formation.

In the hand specimen the alteration is shown by the change of the feldspars. They lose their luster and become whiter (are kaolinized), and the pink color of the orthoclase is apt to be lost. The development of hydrated iron oxide also stains the rock a brownish color. However, quarry specimens taken only a few feet down from the surface will not show these signs of weathering; in many cases specimens only a foot from the surface will appear fresh to the eye. But along joint or fracture planes the weathering has been more active and there the rock may be enough decayed to crumble under slight pressure.

Under the microscope the feldspars which appeared fresh to the eye are found to be clouded to some extent with kaolin: further evidence of change is seen in the development of sericite in them: also by the chloritization of the biotite, and rarely by the presence of calcite.

Dynamic Action.—The rock shows the effect of some dynamic force. The evidence for this lies in several facts: (a) The appearance of the quartz under the microscope—not only does it show undulatory and patchy extinction, but it is also cracked and broken so that at times it is well granulated. (b) The feldspars—there has been a slight cracking along the cleavage directions, and some of the plagioclase lamellæ are curved. The development of the microcline basket structure seems to be the result of dynamic action, and where the microcline is more plentiful it is usually accompanied by a correspondingly greater breaking of the quartz.

The general effect in its greatest expression is to produce a gneissic structure. This varies in degree from simple undulatory and broken quartz, through specimens where groups of broken quartzes and occasional micas have a roughly sinuous parallelism, to those where the material as a whole is distinctly parallel, shown particularly by the bands of granulated quartz with some accompanying mica. However, the force could not have been extreme,—the adjustment of the rock to the strain was accomplished almost entirely by the breaking of the quartz, the feldspars showing relatively few effects.

Fault-Contact Phase.—The greenish rock already described as being found in a few places near the fault contact, is seen under the microscope to be a breccia. All the minerals of the granite are cracked, fragmented and granulated. The quartz naturally has suffered the most because of its lack of cleavage. But the feldspars have by no means escaped the shattering; besides the actual breaking apart of the crystals, the plagioclase lamellæ are bent, folded and faulted; also some microcline has been developed.

As far as mineral content goes, this rock is the same as the main granite with a few modifications, i. e., there is no biotite, for it has all been altered to chlorite, which gives the rock its greenish cast; muscovite is more abundant,—it occurs as disseminated flakes, or as specks and threads scattered quite freely in the groundmass and cracks; a little clay has been developed, both this and the muscovite indicating the presence of heated waters with the dynamic action.

Figure 2 is a free-hand drawing of a thin section of this rock viewed with crossed nicols. This shows to what extent the crystals of quartz (Q) and feldspar (F) have been broken and disrupted. Fragments of these minerals of all sizes fill in the cracks and interspaces; these with sprinklings of muscovite, chlorite, a small amount of clay, and a very few accessory minerals make up the groundmass.

The Pegmatite.—The minerals of the pegmatite are, as in the granite, chiefly quartz and feldspar, with a little mica and some magnetite. The mica is nearly all biotite; in some cases it is segregated somewhat along the margins of the dike type. There seems to have been no unusual pneumatolytic action, at least there are no minerals present which are uncommon in granite—not even tourmaline. At one place a little ilmenite was found with the magnetite.

This non-mineralized character of the pegmatite is a striking fact. It is most easily explained by simply saying that this particular magma did not possess any gases containing boron, fluorine, etc., and so such minerals as tourmaline, topaz, beryl, etc., could not form. But it is also possible that there might have been certain zones throughout the magmatic mass which did not carry pneumatolytic minerals and other zones that did. Such zonal arrangement or distribution might arise from the fact that under conditions of high temperature and pressure, such as would exist in the parent magma, these rarer gases (perhaps in some other active physico-chemical form) would act rather as solvents, with the result that no deposition or formation of any minerals containing them could take place. But such gases, laden with other elements, on passing up through pegmatitic channels, would eventually reach regions where the temperatures and pressures were much lower; here they could no longer act as solvents, but, by combining with various elements and by interacting with other materials present,

Fig. 2.

would have to form minerals, such as tourmaline, beryl, fluorite, etc. These zones, then, would be temperature and pressure zones and would be more or less horizontal in position.

Under this theory, then, pegmatites that were an integral part of the rock as a whole and were formed practically synchronously with it, would not be mineralized, while those parts of the pegmatite which forced out or reached up into the very upper portions of the magma or even into the overlying rocks, would be mineralized. If the surrounding country rock were super-heated, those portions of the pegmatite nearest the parent magma would show less mineralization than those portions farther away, etc.

This theory is only offered as a suggestion.

The texture of the pegmatite varies from a very coarse granite to that degree of coarseness where single feldspar crystals are eight inches long (seen well at Mansfield's Grove).

Quartz Veins.—In the small type of quartz vein the quartz is usually glassy and more or less clear; in the larger type it is usually whiter and duller; either kind may be stained brownish or reddish by iron oxide. The larger also usually has more or less feldspar present.

These quartz veins in origin are closely related to pegmatite. It is a well-known fact that quartz veins are the "end products," so to speak, of pegmatite and this region should be no exception. The fact that pegmatites occur whose central portions are pure quartz, and that quartz veins occur with a great deal of feldspar, points to the close relation between the two.

STRUCTURE.

Gneiss Planes.—These do not always show distinctly and may be so nearly absent as not to show even in a large-sized hand specimen. Their general strike is northeast and southwest, with local exceptions. Their dip is towards the northwest and varies in angle from 0° to 30°; in the western half of the area they are flatter, averaging 10°, while in the eastern portion they are steeper, averaging 20°.

Joints.—Joints are very common; any outcrop will show from one to six or eight sets. There is hardly a direction of the compass that has not a joint direction to match it somewhere in the region. But the most common directions (reading only to the nearest 5° angle) are as follows: N. 5° E., N. 15° E., N. 35° E., N. 40° E., N. 60° E., N. 85° E., N. 5° W., N. 10° W., N. 20° W., N. 65° W., N. 70° W., N. 85° W. Joints that are practically horizontal are fairly common as well.

The joint interval varies from an inch or so to several feet. In some instances the joint faces are well slickensided. Near the fault contact the joints are so numerous and the interval so small that they form an intricately interlaced mass of fractures whose directions it is difficult or impossible to determine. In some places, especially near Lighthouse Point, the joints are curved; sometimes these are scattered among the regular ones and at other times they are in parallel series as in figure 3. The arc of the curve is usually small, a foot or so across, but may in a few cases be several yards in extent.

Fig. 3.

The character of the joints varies from place to place. A good instance of this is in the vicinity of Lighthouse Point; the creek (Morris Creek) that separates this point from Morgan Point is a dividing line,—on the west side, Lighthouse portion, the joints are numerous, the interval small, and curved joints are on the whole common; in many places the rock looks almost shattered; on the east side the joints are less numerous, the interval is large, curved joints are rare, and the rock as a whole much more massive.

Faults.—The most distinct fault (or series of faults) is the one separating the granite from the Triassic. The fact that all members of the eastward-dipping Triassic, anterior, main and posterior with the intervening sandstones and shales, in turn abruptly meet the granite is convincing proof of a fault. Additional evidence of movement is furnished by the great abundance of joints near the contact, numerous slickensides, the brecciated character of the contact granite as seen in thin section under the microscope. The displacement has been at least several thousand feet.

Within the granite formation itself there is little evidence of much faulting. The massive nature of the granite hides any possible movement. An occasional pegmatite dike shows a throw of a few inches or perhaps a foot or so. Abundant joints and slickensides in certain places prove movement but give no measure of the displacement. Such distinct drainage lines as Stony River, Morris Creek, etc., suggest faulting but do not prove it. Undoubtedly there are many faults as yet unobserved: they can only be proven by the minute scrutiny of the jointing, slickensiding, gneiss planes and drainage. As yet sufficient data have not been accumulated to make definite statements.

Contact with the Branford Granite.—The Lighthouse granite merges gradually into the Branford granite. There is no distinct line of contact, there are all transitions from the one kind into the other: there are no stringers or dikes of one kind leading into the other; there are no inclusions of one in the other. These facts, taken into consideration with the fact that both granites are very much alike mineralogically, chemically, etc., show that the two are synchronous in origin,—they are both phases of the same original magma.

AGE AND GENERAL RELATIONS.

It is impossible to determine definitely the age of this rock. The only formation in the region with a known age is the Triassic, and the arkose there is distinctly derived from this and related granite areas; hence the granite is older than the Triassic. It is known to be an integral part of the Lighthouse-Branford-Stony Creek intrusion, which is in turn one of the many New England granitic masses. Kemp says* the Connecticut and Rhode Island granites are Post-Cambrian and Pre-Triassic. Dale states† that the Maine granites are Late Silurian or Devonian in age.

Nothing more definite can be said until the age relations of other Connecticut formations are better known.

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* Bull. Geol. Soc. Amer., x, 372, 1899.

† U. S. G. S. Bull. No. 313, p. 11.

Art. XVII.—*The Silurian Section at Arisaig, Nova Scotia;* by W. H. Twenhofel. With a correlation note by Charles Schuchert.

[Contributions from the Paleontological Laboratory of Yale University.]

While much has been written concerning the Silurian strata at Arisaig and they have often been studied, no section appears in the literature assigning the fossils to their proper horizons. The intermediate position that the fossils of these strata hold in respect to those of the United States and Europe has made such a section particularly desirable. In the summer of 1908 the writer, in the interest of the Peabody Museum of Yale University, had the opportunity of making a zonal collection of fossils from this extensive Silurian section and of studying in detail its stratigraphy.

The writer is under many obligations to Professor Charles Schuchert, without whose assistance in the analysis of the fossils the preparation of this article would have been impossible. He is also much indebted to Mr. Alex. J. McDonald and family, in particular, and to the people of Arisaig, in general, for many favors accorded him during his stay with them.

Review of the Literature.—To the writer's knowledge, the first person to give any definite statement of the geology of northern Nova Scotia was Abraham Gesner, who published in 1836 a work entitled: "Remarks on the Geology and Mineralogy of Nova Scotia." He divided the rocks of the province into Primary Rocks, Trap Rocks, Clay Slate, and Red Sandstone; the last underlying the northern and northwestern areas (1836 : 1)*

The first reference to the Arisaig rocks is found in a paper published by J. W. Dawson in 1845, who described the section as follows: "The section between M'Caras brook (top of section) and Arisaig is occupied by dark shales and thin layers of limestone with a few beds of reddish shale and conglomerate. . . . . . . The rocks dip southwest, but become much fractured as they approach Arisaig" (1845 : 3). He considered them of Silurian age.

The first paleontological work on the section appears to have been done about 1850, as in that year Dawson stated that a small collection of fossils from the upper horizon had been sent to James Hall, who expressed the opinion that they belonged to the age of the Hamilton and Chemung groups (1850 : 351), and statements to this effect appear in his Acadian Geology

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* References are to the list of papers at end of this article.

(1855 : 315). In later papers he modified this view and considered that the strata were the time equivalents of the Clinton to Lower Helderberg of New York, and regarded it as possible that strata lower than the Clinton might be present (1868 : 573). He further stated that the fauna was intermediate in position between that of New York and England.

In 1859 Rev. D. Honeyman, then a minister in the town of Antigonish, published a short paper in the Transactions of the short-lived Literary and Scientific Society of Halifax giving a popular description of the section. Being favorably situated, he spent much time studying the rocks of this and neighboring regions and appears to have made a large collection of fossils from the Arisaig exposures. The results of these and later studies appeared in a number of papers extending from 1859 to 1887 (See list at end of this article). Basing his conclusions on Salter's identification of fossils, he at first considered the section as extending from the Mayhill sandstone to the Upper Ludlow, both of Silurian age; but his later papers express the view that the section begins in the Ordovician, the Utica and Hudson River being represented (1886 a : 318), which view was supported by Hall. He made five subdivisions of the section, which he called, beginning at the base, A, B, B′, C, and D. The most valuable of his papers are those of the years 1864 and 1875. Honeyman deserves a great deal of credit for his earlier work, his sole stimulus being the love that he had for the science of Geology.

The most complete detailed description of the Arisaig strata occurs in the Report of the Canadian Geological Survey for the year 1886. Messrs. Hugh Fletcher and E. R. Faribault of the Survey made the section, which from a structural and petrological standpoint leaves little to be desired, but in failing to cite the fossils collected their work does not give the stratigrapher the needed information to determine the historical record of the rocks described by them. The authors assign the strata to the Silurian, ranging from the Medina to the Lower Helderberg.

The latest work is by Dr. H. M. Ami, who gives a provisional list of fossils, but without locating them in the section. In his last published statements (1901 : 203; 1901 b : 354) with reference to the section, he applies, beginning at the base, the names Arisaig, McAdam, Moydart, and Stonehouse to form divisions of the series; without, however, fixing precise limits to his divisions.

Location and Boundaries.—The Silurian rocks under discussion lie upon the Straits of Northumberland, at the little village of Arisaig, Nova Scotia. They underlie an area about six miles long by one and one-half miles wide (1886 : 41P), washed on the north and northwest by the waters of the Straits of Northumberland and separated from the Pre-Silurian rocks to the southeast by a great fault. On the shore they are overlain unconformably at their western side by a series of conglomeratic sandstones of probable continental origin which are thought to be of Carboniferous age (1886 : 89P), the two series being separated by about fifty feet of fine-grained amygdaloidal trap. To the southwest occur a series of continental sandstones and volcanic tuffs (1901 : 309) which are considered to be of Devonian age. These form the Knoydart formation of Ami (1901 b : 207 ; 1900 a : 303) and from them he has obtained fish remains (1900 a : 309) and a series of tracks (1901 a : 330). The Silurian is underlain unconformably (?) at Arisaig pier and to the east by a series of banded hornstones, red conglomeratic shale, and syenites (1886 : 9P), which in many places have been broken through or covered by fine-grained amygdaloidal trap. A part of these rocks Honeyman and Dawson considered as altered Silurian (1864 : 339 ; 1891 : 565). Fletcher regards them as possibly of Pre-Cambrian age, but states that little can be said of them except that they are older than the "Medina." It is probable that Fletcher is correct, as there appears to be little evidence for the former view.

Structure.—The entire section is well exposed on the cliff and reef along the Strait and by several small brooks crossing it from south to north ; two of them, Doctor's and Arisaig, which are cut in the lower shales, crossing the entire section.

The structure of the rocks is, according to Honeyman, that of a synclinal fold (1864 : 333) ; but it can hardly be considered as a typical syncline, a fact to which he also calls attention (1864 : 335). It may be better characterized as a downfaulted block which has broken south of its mid line, giving rise to a trough which plunges to the southwest.

This conclusion is derived from the fact that the lowest beds of the Silurian have not been seen on the southern side of the area, and by the evidence for faulting given by the topography. The Silurian hills are separated from Eigg mountain or Maple ridge, the Cambro-Silurian upland, by a low area called "The Marshes," which extends approximately parallel to the shore for ten or more miles and marks the fault zone, as Fletcher has pointed out. The beds are tilted away from this fault zone for a short distance, but this is what should be expected. The trough thus formed is much modified by secondary folds and faults which in the lower part of the section reach a maximum. Hence the rocks range from a horizontal attitude just west of the mouth of Arisaig brook to a vertical and overturned attitude at Beach Hill Cove. The general dip of the rocks of the shore is toward the southwest.

The entire section is much fractured and in many places the rocks have been crushed literally to fragments. In the harder rocks the fractures have been filled by quartz and calcite, being in many places so well cemented that when struck the rocks break elsewhere than along the original line of fracture. As many as twelve cemented fractures have been counted on a fragment three inches wide. This cementation is confined to the harder rocks, being practically absent in the shales.

The general direction of the fracture lines is, on the average of those taken, about twenty degrees east of north and thirty degrees west of north; but many variations occur. The section has probably been subjected to pressure more than once in its history.

The greatest fault found occurs at the top of zone 12, where the lower shales have been elevated and abut against higher limestones. In this case the direction is thirty-five degrees west of north.

Some of the joint blocks are very symmetrical. In three beds in which they were particularly regular the following measurements were taken: N. 20° E. by N. 80° W., N. 30° W. by N. 70° E., and N. 28° W. by N. 70° W.

Petrological Divisions.—The rocks can be divided petrologically into the upper shales and limestones having their base on the "Red Stratum," the middle limestones and shales, the middle dark shales, the lower green and dark shales, and the basal shales and arenaceous limestones. These petrological divisions foreshadow the paleontological ones, although from the latter standpoint it is difficult to fix boundaries, as no sharp break occurs in the section except at the fault at the top of zone 12. There is a total thickness of thirty-four hundred and sixty-five feet.

Character and Color of the Rocks.—The rocks comprise shales, ranging from fine-grained carbonaceous paper shales to others decidedly coarse and arenaceous, tough argillaceous limestones, rarely pure limestones, flint-like flags, and fine-grained sandstones. In the lower shales are a few beds of low-grade iron ore, once worked but now abandoned.

The color of many of the rocks on a wave-beaten surface is a dirty green, on a weathered surface a rusty yellow or brown. The shales range through gray, red and black. In the upper part they are red followed by gray and green shades. The thick middle shale horizon is of a dark gray color. The upper half of the lower shales are green; in the lower half dark to black colors predominate. The sandstones and flinty flags have some shade of blue. The limestones range from gray to grayish-green, the latter predominating.

Manner and Place of Deposition.—The strata were formed at no great distance from the shore, as is indicated by their decidedly arenaceous character, the great amount of ripple marking which is particularly characteristic of the upper levels, and the lenticular character of the fine-grained sandstones that are present almost throughout. These last show on a polished or weathered surface wavy and cut-off lines of lamination indicating rapidly changing wave action.

Fossil Content.—The rocks, in general, are fossiliferous throughout; only one stratum, the "Red Stratum" of authors, being without organic remains. They are particularly abundant in the upper red shales and flags, and at many horizons in the middle and lower shales. The impure limestones as a whole contain few fossils, but a series of intercalated nearly pure limestone lenses have them in more than ordinary abundance. These lenses are of two classes: the one wide, but thin, contains merely fragments; the other, about three times as wide as thick, contains many well-preserved fossils, usually of but one species.

Raised Beaches.—Three well-defined raised beaches stand above the present one and slope gently to the northeast. Their heights at Stonehouse brook, the top of the section, are roughly estimated at twenty-five, seventy-five, and one hundred and twenty-five feet. East of McAdam brook the lowest merges into the present one. The lowest two still have very steep cliffs, so their uplift must have been comparatively recent. Whether these beaches rise in elevation westward is not known.

Topography.—The faulting and fracturing of the rocks have had little effect on the upland topography of the area underlain by the Silurian. The brooks crossing the section flow in deep and narrow gorges which do not owe their location to the presence of fractured or faulted zones. Exceptions are McDonald's and Arisaig brooks, which have chosen weakened zones as points for breaking over the shore cliff. The gradient of all the streams is high, falls are present in each, and all the evidence points to recent uplift of the region.

In the shore line topography the story is a different one. Weakened zones have made the smaller detail of the shore. In the soft shales this is not so marked, but in the hard shales and interbedded shales and limestones it is particularly evident. The fractured zones erode readily and the cliff presents a serrate appearance.

The varying hardness of the rocks determines a higher order of detail, shales zones being the location of coves, hard rocks forming points. The latter is well shown by the hornstones of Arisaig pier and by a double example in zone 35, where at the present time is a prominent point; and this appears to have been true at another period of the shore's history, as the first raised cliff has here a point which is a replica of the lowest one.

Description of the Silurian Section.

In order to facilitate the study of the appearance and duration of the species in their true time relations the section is

Honeyman 1864	Dawson 1868, 1891	Fletcher 1886	Ami 1901	Twenhofel 1909	
Division D.	Upper Arisaig. (Lower Helderberg or Ludlow)	Lower Helderberg or E_6. 1038 feet.	Stonehouse Formation.	Division IVb or Stonehouse Formation. (Ludlow)	Red shales and limestones. 97 feet.
			Moydart Formation.		Argillaceous limestones and shales. 978 feet.
Red Stratum.		Red Stratum.		Division IVa or Moydart Formation. (Approximates Louisville or Wenlock time)	Red Stratum. 32 feet.
Division C.		Niagara or E_2. 1293 feet.			Argillaceous limestones and shales. 347 feet.
	Lower Arisaig. (Clinton or Upper Llandovery)		McAdam Formation.	Division III or McAdam Formation. (Rochester or Upper Llandovery) Fault.	Dark shales. Dark shales and argillaceous limestones. 1020 feet.
Division B'. Total thickness B', C, D, 500 feet.		Upper Clinton or E_2. 148+ feet.			
Division B. 170 feet.		Lower Clinton or E_2. 345+ feet.	Arisaig Formation.	Division II or Arisaig Formation. (Clinton or Lower Llandovery)	Green shales with thin sandstones. Dark shales with thin sandstones. 833+ feet.
Division A. 200 feet.		Medina or E_1. 182 feet.		Division I. (Clinton)	Sandstones, limestones, and shales. ?160 feet.

given beginning at the base and extending upward. Forty zones have been established, the character of the sediments being the basis for division. These forty zones have been grouped in five subdivisions. The thickness for each zone has been measured in all cases except where the beds are much disturbed or are covered. In the latter cases the thickness has been estimated or calculated. Figures of attitude are magnetic.

Collections were made at over two hundred different levels in order to delimit any sudden faunal change to definite horizons. The local faunules show that no break in sedimentation occurred and that the disturbances that the rocks have undergone were not extensive except in a single case at the top of the Clinton. The entire collection reveals a fauna of from 140 to 160 species, a total in harmony with Ami's list of 1892. The preliminary identifications of the fossils made by Professor Schuchert relate only to known forms or to comparisons with well-known species. They are chiefly of brachiopods; as the equally abundant pelecypods are nearly all undetermined, awaiting future detailed comparison and description.

Subdivisions of the Arisaig Silurian have been made by four previous writers, as indicated in the appended table, which attempts to show the equivalents of the present section in terms of the older ones.

BASE OF SILURIAN SECTION.

Silurian Division I.

Zone 1 is usually regarded as the equivalent of the New York Medina, but Professor Schuchert states that all the fossils collected belong rather to Clinton time than to the Medina, and that he has found nothing in the collection indicative of the Medina.

1. Base of section at Beach Hill Cove. Here are exposed greenish calcareous sandstones and thick-bedded argillaceous limestone with some shale. Attitude vertical or even overturned. Not seen at Arisaig, where the first strata following the break in the shore cliff are banded hornstones. This zone coincides with Honeyman's Division A (1864: 336), with the Medina or Division E 1 of Fletcher (1886: 37P), and with the lower portion of the Arisaig formation of Ami (1901: 354).

Thickness estimated at.... 160 feet.

Fossils are scarce and difficult to collect and were found only in the upper seventy-five feet which is exposed at the east and west points of the cove. *Lingula* cf. *oblonga*, *Dalmanella* cf. *elegantula*, *Cornulites flexuosus*, and *Zaphrentis* cf. *bilateralis*.

CLINTON ZONES.

Silurian Division II, or Arisaig Formation.

Zones 2 to 12 are correlated with the New York Clinton on the basis of the presence of *Monograptus clintonensis*, *Retiolites geinitzianus venosus*, and *Anoplotheca hemispherica*. Division II begins with dark carbonaceous paper shales, and has in its upper half green shales with fine-grained sandstones. It is believed to be coincident with Divisions B and B′ of Honeyman (1864: 333), to include somewhat more than the Upper and Lower Clinton or Division E2 of Fletcher (1886: 37P), and to form the upper portion of the Arisaig formation of Ami (1901: 394).

In this division there is an estimated thickness of over eight hundred feet, which is probably less than the true thickness, as some of the strata have been lost by faulting.

2. From Arisaig Pier to the Lobster Factory there are no outcrops. At the middle of Beach Hill Cove are exposed about one hundred feet of black carbonaceous paper shales that partly or wholly lie below zone 3. Strike almost E.–W., but varying ten to twelve degrees either side. Fossils are scarce, due to the much weathered condition of the shales. Base of Honeyman's Division B and Lower Clinton of Fletcher's section.

3. Broken down cliff of dark to black rusty weathering papery shales. Beds much disturbed, and in part the strike is almost that of the shore.

Estimated thickness ...... 100 feet.

Fossils abundant: *Anoplotheca hemispherica*, *Anabaia anticostiana*, *Lingula* cf. *oblonga*, *Acaste downingiæ*.

4. Dark-gray to green and black fine-grained soft shales, weathering rusty. Much disturbed. Strike N. 50°–70° W.; dip 30°–50° W., with many variations.

Estimated thickness ...... 215 feet.

Fossils fairly abundant: *Monograptus clintonensis*, *Anoplotheca hemispherica*, *Anabaia anticostiana*, *Cornulites flexuosus*, *Calymena* cf. *tuberculata*.

5. Dark-gray somewhat papery shales with a few hard bands; all weather rusty. Strike variable. N. 60°–70° W.; dip 30°–40° W.

Estimated thickness ..... 50 feet.

Monograptus clintonensis, *M. priodon chapmanensis*, *Retiolites geinitzianus venosus*, *Orbiculoidea tenuilamellata*, *Dalmanella elegantula*, *Schuchertella* sp., *Chonetes tenuistriata*, *Anoplotheca hemispherica*, *Anabaia anticostiana*, *A. depressa*, *Cornulites flexuosus*, *C. distans*.

6. Dark-gray splintery shale without hard bands. The base of this zone is about fifteen yards west of the present

mouth of Arisaig brook, but by faulting it is brought to view in the mouth of the brook. Strike N. 86° W.; dip 16° W.

Thickness ---------------- 23 feet.

This zone appears to coincide with the base of Honeyman's Division B′ and the Upper Clinton of Fletcher's section. Fossils: *Monograptus priodon chapmanensis*, *Dalmanella elegantula*, *Anabaia depressa*, *Cornulites distans*, and *Dalmanites sp.*

7. Green arenaceous micaceous shales and fine-grained sandstones in beds from one to six inches thick. Much fractured. Attitude almost horizontal. Strike N. 20–90° W.; dip 0–2° W.

Thickness ----------------- 30 feet.

Fossils fairly abundant: *Monograptus clintonensis*, *Orbiculoidea tenuilamellata*, *Dalmanella elegantula*, *Chonetes tenuistriatus*, *Camarotœchia* near *equiradiata*, *Anabaia anticostiana*, *Anoplotheca hemispherica* (rare), *Schuchertella sp.*, *Avicula emacerata*, and fragments of *Eurypterus.*

8. Green shales and thin lenticular fine-grained sandstones. Strata in a small synclinal fold.

Estimated thickness - ----- 30 feet.

Fossils very common, especially graptolites: *Monograptus clintonensis*, *M. priodon chapmanensis*, *Retiolites geinitzianus venosus*, *Orbiculoidea tenuilamellata*, *Leptæna rhomboidalis* (first appearance), *Chonetes tenuistriatus*, *Camarotœchia* near *equiradiata*, *Anoplotheca hemispherica* (small and rare), *Cornulites distans*, *Avicula* cf. *rhomboidea*, *Pterinea honeymani*, *Modiolopsis* (?) cf. *primigenia*, *Dalmanites sp.* and fragments of *Eurypterus.*

9. Light-green, more or less arenaceous shales with numerous lenticular fine-grained sandstones. A shale layer three feet thick full of *Leptæna rhomboidalis* occurs. The beds are much disturbed and thickness is uncertain.

Estimated thickness -------- 66 feet.

Monograptus clintonensis, *Chonetes tenuistriatus*, *Camarotœchia* cf. *obtusiplicata*, *Rhynchonella* cf. *robusta*, *Anoplotheca hemispherica* (rare), *Serpulites* cf. *dissolutus*, *Cornulites distans*, *Avicula rhomboidea*, *Modiolopsis* (?) cf. *primigenia*, and *Eurypterus* fragments.

10. Light-green, soft, somewhat papery shales weathering a dirty greenish-yellow and many thin lenticular fine-grained sandstones. This zone begins at a small promontory forming the west end of a synclinal fold which is believed to be the disturbance of zone 18 of Fletcher's section and ends at a fault about forty yards east of the mouth of Smith's brook. This appears to be the fault described by Fletcher (1886: 39P) and

marks the base of his Niagara. Strike N. 55° W.; dip 10°–35° W.

Estimated thickness -------- 66 feet.

Chonetes tenuistriatus, *Rhynchonella* cf. *robusta*, *Anoplotheca hemispherica*, *Cornulites distans.*

11. Greenish-gray shales with some much shattered lenticular fine-grained sandstones. Zone ends at a small gulch in the cliff, that is here forty or more feet high and crowned by stratified glacial material. Strike N. 54° W. to N. 73° E.; dip 34° W. to 10° E.

Estimated thickness ------- 63 feet.

Very fossiliferous: *Monograptus clintonensis*, *Retiolites geinitzianus*, *Orbiculoidea tenuilamellata*, *Dalmanella elegantula*, *Leptæna rhomboidalis*, *Chonetes tenuistriatus*, *Camarotœchia* cf. *obtusiplicata*, *Wilsonia* cf. *saffordi*, *Anoplotheca hemispherica*, *Cornulites distans*, *Dalmanites*, *Conularia.*

12. Dark-gray shales, weathering rusty, with very few hard bands. Beds much disturbed.

Thickness thought to be near --- 80 feet.

Fossils abundant, particularly graptolites: *Monograptus clintonensis*, *Leptæna rhomboidalis*, *Chonetes tenuistriatus*, *Anoplotheca hemispherica*, *Modiolopsis* (?) cf. *primigenius*, *Calymene*, and *Dalmanites.*

Higher Niagaran Zones

Silurian Division III, or McAdam Formation.

Following zone 12, the highest member of the Clinton, there is a fault of considerable importance, the eastern limb of which has been elevated and a part of the strata lost. The fossils of zone 13 are markedly different from those below and yet a number of species, chiefly pelecypods, range on both sides of the fault. Apparently the throw has not been extensive. The species of zones 13 to 27 are not many in number; but indicate, rather distantly however, the Rochester shale. This time equivalence is best seen in the presence of *Monograptus* cf. *riccartoensis*, *Dalmanella* cf. *edgelliana*, *Camarotœchia neglecta*, *C.* cf. *obtusiplicata*, *Spirifer crispus*, and first appearance of large *Atrypa reticularis.* Other species that help to confirm this correlation could be mentioned, but most of these have a longer upward range. In fact, all the zones about the fault have an indigenous fauna that gradually changes into those of the higher beds. Division III is believed to coincide, in the main, with the McAdam formation of Ami (1901: 304), in part with the Niagara or Division E3 of

Fletcher (1886: 37P), and in part with Division C of Honeyman (1864: 333). It consists chiefly of dark splintery arenaceous shales with a total thickness of one thousand and twenty feet.

13. More or less thick-bedded greenish-gray to dark-gray rubbly argillaceous limestone and splintery micaceous-arenaceous shale. The zone is much disturbed and at its base is thrown into a small anticlinal fold of which the eastern limb has been broken off and elevated an unknown distance. Strike N. 56°–72° W.; dip 32°–37° W.

Estimated thickness ...... 140 feet.

If one may judge from Honeyman's map (1864: 336), this zone forms the base of his Division C. Fossils abundant: *Mariacrinus* (?), *Dalmanella elegantula*, *Leptæna rhomboidalis*, *Stropheodonta sp.* 1, *Camarotœchia neglecta*, *C.* cf. *obtusiplicata*, *Atrypa reticularis* (first appearance).

14. Dark-blue to gray micaceous-arenaceous shales with a few flags and thin limestones to a large trap bowlder at foot of cliff. Strike N. 76° W.; dip 32° W.

Thickness .... 33 feet.

Fossils abundant: *Dalmanella elegantula*, *Camarotœchia neglecta*, *Tentaculites*, *Homalonotus dawsoni* (?).

15. Greenish-gray interbedded arenaceous-argillaceous limestone and shale to McAdam's boat landing. Zone much disturbed. Strike N. 64° W. to N. 57° E.; dip 42° W. to 39° E. Much of the shore follows line of strike.

Thickness estimated at..... 63 feet.

Pholidops implicata, *Dalmanella elegantula*, *D.* n. sp. very large, like *D. edgelliana*, *Camarotœchia neglecta*, *Pterinea emacerata*, *Calymene*, *Homalonotus dawsoni* (?).

16. Dark-gray shales. Strike N. 64° W.; dip 33° W.

Thickness .... 24 feet.

Fossils common: *Dalmanella elegantula*, *Camarotœchia neglecta*, *Tentaculites*.

17. Greenish-gray and dark-gray, crumbling, more or less arenaceous shales. Strike N. 75° W.; dip 37° W.

Thickness .... 88 feet.

Fossils scarce: *Dalmanella elegantula*, *Camarotœchia neglecta*.

18. Hard shales, breaking into dagger-like fragments, and knotty calcareous flags with nearly pure limestone lenses. Strike N. 80° W.; dip 40° W.

Thickness .... 49 feet.

Fossils scarce: same as in 16 with *Chonetes tenuistriatus*.

19. Dark soft mud-shale with many fossils. Strike N. 72° W.; dip 40° W.

Thickness .... 24 feet.

Dalmanella elegantula, *Camarotœchia neglecta*, *Tentaculites*, *Bucanella trilobata.*

20. Greenish-gray to dark arenaceous shale with more or less thick beds of argillaceous limestones that are much veined by quartz and calcite. Zone ends at mouth of McAdam brook. Strike N. 75°–80° W.; dip 40°–48° W.

Thickness .... 123 feet.

Fossils scarce except in a few lenticular limestones: *Pholidops implicata*, *Dalmanella elegantula*, *Camarotœchia neglecta*, *C.* cf. *obtusiplicata*, *Tentaculites*, *Bucanella trilobata.*

21. Black, somewhat papery, soft carbonaceous shales with no hard bands. Strike N. 64° W.; dip 36° W.

Thickness .... 30 feet.

22. Dark-gray to black carbonaceous splintery shale with a few hard bands and many oblate spheroidal concretions. Strike N. 65–80° W.; dip 35–40° W.

Thickness .... 144 feet.

Dalmanella elegantula, *Chonetes tenuistriatus*, *Camarotœchia neglecta*, *C. obtusiplicata*, *Leptæna rhomboidalis*, *Spirifer crispus* (first appearance), *Grammysia* (small form), *Calymene tuberculata.*

23. Dark-gray to black soft carbonaceous shale. Strike N. 70° W.; dip 39° W.

Thickness .... 17 feet.

Fossils as in 22.

24. Dark-gray to black splintery arenaceous and finely laminated carbonaceous shales. At various levels occur thin beds of lenticular fine-grained sandstones and very large oblate spheroidal concretions. Near the top is a bed thickly crowded with pelecypods. Strike variable but in general N. 70° W.; with dip 45° W.

Thickness .... 170 feet.

Dalmanella elegantula, *Chonetes tenuistriatus*, *Camarotœchia neglecta*, *C. obtusiplicata*, *Atrypa reticularis*, *Spirifer crispus*, *Grammysia* (small forms), *Bucanella trilobata.* About thirty-five feet from the top occur *Monograptus* cf. *riccartoensis* in great abundance.

25. Dark-gray to black carbonaceous slaty shales in thick beds with some lenticular fine-grained sandstones showing wavy lines of lamination. Strike N. 43°–54° W.; dip 62° W.

Thickness .... 44 feet.

Fossils abundant, but poor: *Dalmanella elegantula*, *Chonetes tenuistriatus*, and an abundance of *Cleidophorus*.

26. Gray and greenish-gray argillaceous limestones and slaty flags. Steeply upturned. Strike N. 46° W.; dip 62° W.

Thickness .... 15 feet.

Fossils as in 24.

27. Greenish-gray argillaceous-arenaceous limestones in thick beds, many of which are beautifully ripple marked. Strata much disturbed and thrown into a synclinal fold.

Thickness estimated at...... 56 feet.

Division IVa, or Moydart Formation.

This division is not marked basally by a sudden introduction of new faunal elements and no marked petrologic change occurs, there being a gradual increase in the amount of limestone with progress upward. The top of Division IVa is drawn at the upper limit of the "Red Stratum" or zone 32. The total thickness is three hundred and seventy-nine feet.

The strikingly new and characteristic species is *Chonetes novascotica* that gradually becomes the dominant fossil of Division IV, attaining to larger and larger size until in Division IVb specimens are more than one inch long on the hinge line. *Spirifer crispus* of Division III is succeeded in IVa by *S. subsulcatus* and the latter gives rise to *S. rugæcosta* that attains to typical development and large size in Division IVb.

Division IVa forms the upper portion of Honeyman's Division C (1864: 336), the upper portion of Fletcher's Niagara or Division E3 (1886: 38P), and is believed to form the lower portion of the Moydart formation of Ami (1901: 354).

28. Greenish-gray more or less arenaceous-argillaceous limestone of a prismatic and nodular character, alternating with thick beds of bluish-gray shale that break into irregular fragments. Strike N. 80° W.; dip 30° W.

Thickness estimated at..... 117 feet.

Fossils are scarce but some of the limestone lenses are rich in them. Large crinoid columns, thick branches of a ramose monticuliporoid bryozoan, *Dalmanella elegantula*, *Chonetes novascotica*, *Camarotœchia* cf. *formosa* or *borealis*, *Spirifer subsulcatus*, *Pterinea emacerata*, *Grammysia acadica*, *Serpulites* cf. *dissolutus*, *Orthoceras sp.* 1, *Diaphorostoma* cf. *niagarensis*, *Homalonotus dawsoni*.

30. Bluish to greenish-gray shales and thin limestones. Beds little disturbed. Strike N. 75° W.; dip 37° W.

Thickness .... 32 feet.

Fossils abundant: *Chonetes novascotica*, *Camarotœchia* cf. *formosa*, *Homœospira* cf. *acadiæ*, *H.* cf. *evax*, *Spirifer subsulcatus*, *Orthoceras sp.* 1, *O. sp.* 2, *Homalonotus dawsoni.*

31. Greenish-gray more or less heavy-bedded argillaceous limestones, some beds of nearly pure limestone, bluish-gray mudstones cleaving into thin beds, soft shales, and splintery arenaceous flags. The zone begins just east of the mouth of McDonald's brook. Strike N. 72° W.; dip 36° W.

Thickness ---------------- 101 feet.

Ramose bryozoa as in 28; *Camarotœchia* cf. *formosa;* an *Eatonia medialis*-like rhynchonelloid, but not at all this species; *Spirifer subsulcatus; Homœospira* cf. *acadiae; Orthoceras sp.* 2; *Calymene tuberculata; Homalonotus dawsoni; Cornulites proprius.*

32. The "Red Stratum." A brick-red shale of which the upper thirty feet is prismatic and locally nodular. Shows little evidence of stratification except near its base. It is rather sharply differentiated from the overlying green shales, but grades into the subjacent zone. Twenty feet below the top is a nodular band ten inches thick. The nodules are bright green to greenish-white in color and have their longer axes transverse to the bedding. The same color shows along the fracture lines. At the base are included twenty-seven inches of thin beds of ferruginous limestone and shale which form the transition to zone 31. Strike N. 68° W.; dip 40° W.

Thickness ----------------- 32 feet.

Division IVb, or Stonehouse Formation.

This subdivision has its base on the top of the "Red Stratum" and extends to the amygdaloidal trap at the top of the Silurian section. It is faunally characterized by the large size of the species and especially by the abundance of *Pholidops implicata*, *Chonetes novascotica*, *Spirifer rugæcosta*, *Homœospira, n. sp.* 1, *Grammysia acadica*, *G. rustica*, *Pteronitella venusta*, *P. curta*, *Calymene tuberculata*, *Acaste logani*, *Homalonotus dawsoni*, and an abundance of *Beyrichia pustulosa* and *B. æquilatera.* The subdivision has a total thickness of one thousand and seventy-five feet. It corresponds to the upper portion of the Moydart formation of Ami and the whole of his Stonehouse formation (1901: 354). It coincides with Division D of Honeyman, as described in the Quarterly Journal of the Geological Society of London (1864: 336), and to the Lower Helderberg or Division E6 of Fletcher (1886: 37P).

33. Very deep-green shales with a few thin lenticular bands of limestone. Strike N. 58°–66° W.; dip 40° W.

Thickness .... 33 feet.

34. Gray to bluish-green, rubbly more or less arenaceous-argillaceous limestone in thick beds; many of which are of a lenticular character. In many places ripple marked and much fractured and veined by quartz and calcite. In the lower beds occur small black nodules. Strike N. 48° W., changing to N. 58° W. near the base; dip 40° W.

Thickness .... 342 feet.

Fossils not common: *Stropheodonta* n. sp. 1, *Leptæna rhomboidalis*, *Chonetes novascotica*, *Atrypa reticularis*, *Spirifer subsulcatus* (large), *S. rugæcosta*, *Homœospira* cf. *evax*.

35. Fauna and beds of same character as in zone 34 except that the ripple marking is more prominent and characterizes the zone. Strike N. 38° W.; dip 38° W.

Thickness .... 179 feet.

36. Greenish-gray quartz-veined rubbly arenaceous-argillaceous limestone in thick beds, and grayish-blue splintery flags with some green and rusty-purple shale to the mouth of McPherson's brook. Often ripple marked. Strike N. 50° W.; dip 40° W.

Thickness .... 111 feet.

Chonetes novascotica, *Stropheodonta* sp. 1, *Atrypa reticularis*, *Spirifer rugæcosta*, *Grammysia acadica*, *Pteronitella venusta*.

37. Grayish-green arenaceous shales, argillaceous limestone, and splintery grayish-blue flags. Much veined and ripple marked. Strike N. 50° W.; dip 30° W.

Thickness .... 67 feet.

Pholidops implicata, *Chonetes novascotica*, *Camarotœchia* cf. *borealis* (Davidson's fig. 224–26), *Spirifer rugæcosta*, *Pteronitella venusta*, *Grammysia*, *Calymene tuberculata*, *Homalonotus dawsoni*.

38. Greenish-gray argillaceous limestone and shale with grayish-blue flinty flags. All in thick beds and much veined by quartz and calcite. Strike N. 57° W.; dip 37° W.

Thickness .... 110 feet.

Many fossils. *Chonetes novascotica*, *Camarotœchia* cf. *borealis*, *Spirifer rugæcosta*, *S. subsulcatus*, *Homœospira n. sp. 1*, *Cornulites proprius* (?), *Calymene tuberculata*, *Orthonota angulifera* (?), many bivalves.

39. Red and grayish-green shales, gray and red argillaceous limestones, and bluish-gray splintery flags to the mouth of

Stonehouse brook. Very extensively veined by quartz and calcite. Strike N. 52° W.; dip 43° W.

Thickness .... 136 feet.

Many fossils: *Pholidops implicata*, *Chonetes novascotica*, *Camarotœchia* cf. *nucula*, *C.* cf. *borealis*, *Spirifer rugæcosta*, *Homœospira n. sp. 1*, *Cornulites proprius* (?), many bivalves, *Beyrichia æquilatera*, *B. pustulosa*, *Acaste logani*, *Calymene tuberculata*, *Homalonotus dawsoni*, *Eurypterus* or *Pterygotus* fragment.

40. Red shales and limestones with grayish-blue splintery flags dotted with very bright green patches. In the flags the fossils occur in thin calcareous layers attached to their under sides. Strike N. 63° W.; dip 30° W.

Thickness .... 97 feet.

Has in addition to the fossils of 39 the following: *Schuchertella subplana*, *Pteronitella venusta*, *Bucanella trilobata* (large), *Grammysia acadica*, *Goniophora transiens*.

41. Amygdaloidal trap overlain unconformably by Carboniferous (?) sandstone. Apparently has altered neither the Silurian strata nor the sandstone, but Silurian contact obscure. Strike of upper contact, N. 32° E.; dip 23° E.

Estimated thickness... 40 to 50 feet.

VOLCANIC ROCKS AT THE BASE OF THE SILURIAN.

On a previous page mention has been made of the rocks underlying the Silurian strata and it was stated that these rocks have been for the most part considered as altered sedimentaries. For complete details regarding them the reader is referred to the Report of the Canadian Geological Survey for the year 1886, page 9P. Studies made of these rocks in the field led the writer to the conclusion that practically all are of volcanic origin, which seems also to have been the view of Fletcher (1886: 9P). Since, however, they have so often been referred to as altered sedimentaries, it seemed desirable to investigate them by chemical and petrological means, and with this purpose in view specimens were collected from Arisaig Pier to Frenchman's Barn. These specimens have been studied by the writer in the Petrological Laboratory of the Sheffield Scientific School under the supervision of Professor L. V. Pirsson and in the Kent Chemical Laboratory under the direction of Professor F. A. Gooch; to each of these gentlemen the writer acknowledges his indebtedness.

The rocks, as first seen at Arisaig Pier, consist of relatively light-colored hornstones which show banding to a high degree. Eastward they become coarser and darker and at the western base of the prominent rock mass known as Frenchman's Barn appears a bed of red shale containing rounded bowlders overlain by a thick-bedded series of dark-green stratified rocks. Both the shale and the dark-green rocks have an almost vertical attitude. Along lines of fracture all the rocks have a light-green color and there is a conspicuous irregular band of like color, varying from fifty to seventy-five feet wide, which is said to have been traced for more than a mile (1886 : 9P). Throughout the whole, at different points, are younger masses of amygdaloidal trap.

A chemical examination of the light-colored hornstone of Arisaig Pier gave the following analysis, which was done in triplicate to minimize possibilities of error:

SiO_2	76·70	per cent.
Al_2O_3	12·98	"
Fe_2O_3 FeO	0·25	"
CaO	0·54	"
MgO	0·06	"
K_2O	4·14	"
Na_2O	4·92	"
H_2O	0·59	"
TiO_2	trace	"
CO_2	"	"
P_2O_5	0·31	"
Total	100·53	"

This analysis corresponds very closely to that of a rhyolite, as is evident from the high per cent of alkalies present, which would hardly be the case were the rock an altered sedimentary. An analysis of the red shale shows that it is, in all probability, of sedimentary origin. Examination of the rock in thin sections gave abundant evidence that the hornstones are none other than rhyolites. The thin sections show that the hornstones are made up of alternating bands of a very dense and less dense material, in the latter of which the minerals can be readily determined. These consist of quartz and alkalic feldspar, the quartz acting as a sort of sponge for the feldspar and giving what is known as micropoikilitic structure. Numerous microlites, of which the character has not yet been determined, are present. Many small flakes of chlorite, along minute lines of fracture and in places of alteration, explain the green color common in many places, and a section made from the green band shows that the color in this particular section is also due to chlorite. Pieces of angular fragments, characteristic of extrusive volcanic rocks, are present in the dense bands. The thin sections show that the dark green rock overlying the red shale is a volcanic breccia, containing, in addition to the angular fragments of glass and fine material, pieces of quartz and feldspar. Small flakes of clay are also present, which appear to be due to alteration subsequent to deposition.

Correlations by Charles Schuchert.

Mr. Twenhofel gathered a large collection of the Arisaig fossils in over 200 lots from as many horizons in the section of 3465 feet. In looking over this mass of material one is impressed with the strangeness of this Silurian fauna, which is more European in derivation than American. None of the characteristic Silurian fossils of the United States is present excepting a few forms like *Anoplotheca hemispherica*, *Camarotœchia neglecta*, *C. obtusiplicata*, and a few other brachiopods occurring in all Silurian districts. On the other hand, the pelecypods remind decidedly of Westmoreland, England, and yet the widely distributed European *Cardiola interrupta* is not present, but is said to occur in northern Maine. Another peculiarity of this Silurian fauna is the almost complete absence of corals, but this fact may be ascribed to the muddy and sandy shore condition of this sea. The only American Silurian region having a fauna suggesting direct marine connections is that of the Appalachian trough, best known about Cumberland, Maryland.* A comparison with this region shows, however, that the Arisaig fauna has its own decided characteristics; but that it still has by far more in common with the Cumberland trough extending to Clinton in eastern New York, than with the faunas of western New York or the Mississippi Valley. Another striking fact is that even though the Arisaig section is a very thick one and though it has been stated more than once that the Helderbergian faunas or their equivalents are present, there are no fossils in these strata suggesting anything more recent than the Ludlow (of the Christiania area of Norway).

Division I.—This horizon is usually regarded as equivalent to the Medina of New York; but on grounds other than its position, there is not the slightest evidence for this correlation. As yet no *Anoplotheca hemispherica* have been gathered here, but the other fossils are those of Division II. None of the typical Medina fossils is present and until such are found these strata are best regarded as of Clinton or Lower Landovery time.

Division II or Arisaig formation.—The lowest faunas of the Arasaig series are distinctly Silurian and there is nothing present representing the thick transition series between the

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* See Prouty, this Journal, Dec., 1908, pp. 553–574.

Richmond and Clinton equivalents, so well developed at Anticosti in the St. Lawrence embayment. The section practically begins with the *Anoplotheca hemispherica* faunas, clearly of Clinton time in America and the Lower Llandovery of northern Europe. This biota maintains itself through 800 feet of shales and sandstones when the continuing deposits are cut out by a fault of unknown magnitude. To this division may well be applied Ami's formational name Arisaig. The guide fossils of Division II are: *Monograptus clintonensis*, *M. priodon chapmanensis*, *Retiolites geinitzianus venosus* (The equivalents of these graptolites do not appear in the Norwegian section earlier than the upper division of the Upper Llandovery), *Chonetes tenuistriatus*, *Anabaia anticostiana*, *A. depressa* (=*Atrypa depressa* Sowerby, which appears in the Norwegian section at the top of the Lower Llandovery and continues throughout the Upper Llandovery), *Anoplotheca hemispherica* (restricted in the Norwegian section to the Lower Landovery), *Cornulites distans*, and *Acaste downingiæ.*

The time equivalent of these fossils is clearly Clinton, but the recent unpublished work of Ulrich and Ruedemann shows that this formation at Clinton, New York, not only embraces the *Anoplotheca hemispherica* fauna, but also continues upward well into the equivalent of the Rochester of western New York. The Arisaig Division II is therefore thought to be equivalent to the lower beds of the eastern New York Clinton, i. e., beds having *Anoplotheca hemispherica*, and all of the Lower and possibly a part of the Upper Llandovery of Norway as recently described by Kiaer.*

Division III or the McAdam formation.—Above the only pronounced fault of the Arisaig section the strata continue without interruption to the amgydaloidal trap. Throughout a thickness of 2575 feet the faunas are continuously of one progressive development, and one can trace the evolutional changes of the various elements from small individuals of the lower beds to the often much larger ones at the top of the Arisaig section. As this series is a very thick one, it has been deemed advisable to subdivide it into three divisions, and particularly so because this has been done by our predecessors in the same field.

Division III, consisting essentially of shales, has a thickness of 1020 feet. The fauna is poorly preserved and is not a large one, but when the many pelecypods are studied, a longer list will be at hand than can be given at this time. Many of the species extend throughout these beds to the top of Division IV. As guide fossils of Division III may be mentioned *Monograptus riccartœnsis*, *Camarotœchia neglecta*, *C.* cf. *obtusiplicata*,

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* Das Obersilur im Kristianiagebiete, 1908.

Dalmanella cf. *edgelliana* (sometimes compared with *D. subcarinata*), *Chonetes tenuistriatus*, *Spirifer crispus*, and *Atrypa reticularis*. These fossils, and the absence of the guide Clinton or Lower Llandovery fossils, seem to indicate that Division III is to be correlated with the Rochester (probably within the lower Rochester) and the Upper Llandovery including probably also the Lower Wenlock.*

Division IVa or Moydart formation.—Basally this division is on physical characters inseparable from Division III, and on faunal grounds an arbitrary line of separation is drawn where the first *Chonetes novascotica* appear. The top of Division IVa is placed at the "Red Stratum," an horizon noted by all geologists studying the Arisaig series. The rocks of this division consist of argillaceous limestones and shales having a united thickness of 379 feet. The guide fossils are, earliest appearance of *Chonetes novascotica*, suggesting the European *C. striatella; Wilsonia wilsoni* in typical specimens like those figured by Davidson from the Wenlock; a rhynchonelloid suggesting *Eatonia medialis*, but has a lamellose instead of a striate surface; *Camarotœchia* cf. *borealis* or *formosa; Spirifer subsulcatus;* a later and larger development of *S. crispus; Homœospira acadiæ; Orthoceras* suggesting the Ludlow *O. striatum; Homalonotus dawsoni; Calymene tuberculata;* and locally an abundance of ramose bryozoa, but of only one or two species. Faunally, this horizon is intimately connected with that of Division III, and as the species compare in development best with those of the middle Niagaran, as the Waldron and Louisville faunas, the time equivalence of Division IVa is thought to be of about this time. In North Europe the Wenlock has the nearest faunal approach, and according to Kiaer's work the Moydart fossils agree best with the Upper Wenlock of Norway.

Division IVb or Stonehouse formation.—This division begins basally at the "Red Stratum," and is terminated by the amygdaloidal trap. The lower 978 feet consist of argillaceous limestone and shales, of which about 840 feet have light green to gray colors. A red tinge begins to appear in zone 39 and the final 97 feet of zone 40 are of a decidedly brick red color with some green blotches, and shale predominates here over the limestone.

The fauna is essentially that of Division IVa, but the species have all attained to larger growth and the individuals are present in greater numbers and better preservation. *Chonetes novascotica* is dominant in fine large specimens throughout this division and in this reminds of the similar development of *C. striatella* of the Ludlow horizons of Norway (see Kiaer).

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* See Kiaer, Das Obersilur im Kristianiagebiete, 1908.

Other common fossils are *Pholidops implicata* (=*Crania acadiensis* Hall), *Spirifer subsulcatus, S. rugæcosta* (a development out of the previous species and closely related to *S. bijugosa* McCoy of Ireland, said to be of Wenlock time), *Schuchertella subplana* (rare), *Rhynchonella nucula* (a Ludlow guide fossil), *Cornulites flexuosus* (reappearance of the lower form), *Bucanella trilobata* (much larger than those of lower horizons), *Grammysia acadica* (rather indicative of Ludlow), *G. rustica*, *Goniophora transiens*, *Pteronitella venusta*, *P. curta*, *Beyrichia pustulosa*, *B. æquilatera*, *Acaste logani*, *Calymene tuberculata* (large), and *Homalonotus dawsoni* (a flat-headed form unlike any other American species, attaining to a length of about three and one-half inches. One imperfect specimen of apparently the same form indicates a size of 5 inches or more. This species appears in Division II).

From this evidence Division IVb correlates clearly with the Ludlow. Kiaer cites *Megalomus gothlandicus* from the Middle Ludlow, and as this fossil occurs in Gotland with Trimerella, it would appear that Division IVb has its nearest time equivalent in the Guelph of Interior America.

Along the shore in the upper part of Stonehouse formation Mr. Twenhofel picked up the cast of a ventral valve of a large Spirifer related to *S. macropleura* and *S. niagarensis.* The specimen is out of a brick-red shale and is as large as the former species but has more plications and is a flatter form, in both of which characters it approaches *S. niagarensis.* This fossil seems to indicate proximity to Helderbergian (New Scotland) deposits, but as it is not *S. macropleura*, a form also unknown in the Helderbergian deposits of Dalhousie, New Brunswick, and Gaspé, Quebec, it does not seem wise to lay much correlation value upon it for the present.

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Art. XVIII.—*The Fish Fauna of the Albert Shales of New Brunswick*[*]; by Lawrence M. Lambe, Geological Survey Branch, Department of Mines, Ottawa, Canada.

The bituminous shales of Albert and Westmoreland counties, New Brunswick, which are attracting, at the present time, considerable attention on account of their richness in oil and sulphate of ammonia, have long been known to hold very abundant and well-preserved remains of fishes of the family Palæoniscidæ. These fishes are particularly numerous at the Albert mines, where, for some years during the latter half of the past century, the mineral *albertite* was extracted in paying quantities. The beds at this locality consist principally of brown or gray, readily splitting, sometimes almost papery, shales, and nearly black "oil bands" reaching a thickness often of 6 feet. Associated with the Albert shales, and lying conformably beneath them, are greenish-gray conglomerates, the whole having an estimated thickness of about 1000 feet. The shales are sometimes much disturbed, being in places faulted and inclined at high angles. They are generally overlaid unconformably by massive beds of dark-colored conglomerate associated with sandstone.

It is in the brown shales principally that the fish remains occur, but excellently preserved specimens are also found in the thick beds as well as in nodules. The majority of the specimens show the full contour of the fish, with the fins in place, but the head is usually so crushed as to obscure the relationship of its constituent parts. In many examples very full details are given of the structure of the scales, fin rays, etc. and of their surface ornamentation.

Dr. Charles T. Jackson, in 1851,[†] described three species from the Albert mines, viz.—*Palæoniscus alberti*, *P. brownii* and *P. cairnsii*, besides referring to a number of specimens which were not at the time named specifically.

In 1877[‡] Dr. Ramsay H. Traquair assigned *Palæoniscus alberti* and *P. cairnsii* to his genus Rhadinichthys, and *P. brownii* to Elonichthys.

In the same year[§] Sir J. William Dawson added to this particular fauna by describing *Palæoniscus* (*Rhadinichthys*)

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[*] Communicated with the permission of the Director of the Geological Survey.

[†] Report on the Albert Coal Mine, etc., Boston, 1851.

[‡] Quart. Jour. Geol. Soc., vol. xxxiii, p. 559, 1877.

[§] Canadian Naturalist, new series, vol. viii, p. 338, 1878. Part 6, pp. 315–378, published December 1877.

modulus and *P. jacksonii.* The type material of the former species was from Beliveau in the northeastern continuation of the Albert shales area and about six miles, in a straight line, from the Albert mines; the latter species was based on one of Dr. Jackson's largest specimens from the Albert mines (*Palæoniscus sp.*, fig. 4 of Jackson's original plate I) in conjunction with specimens from the same locality in Dawson's collection and in that of Dr. G. F. Matthew of St. John, N. B.

Sir Philip Gray Egerton,* and much later Dr. John Strong Newberry† and Dr. Arthur Smith Woodward,‡ and recently Dr. Charles R. Eastman,§ have referred to all or some of these species in greater or less detail.

In a paper, to be published shortly by the Geological Survey of Canada, on the "Palæoniscid Fishes of the Albert Shales of New Brunswick," the writer gives the result of a study of the fish fauna of the shales of Albert mines and vicinity as revealed by the collections of the Geological Survey and by Jackson's and Dawson's type material. The writer takes this opportunity of expressing his thanks to Dr. Charles R. Eastman and Mr. Samuel Henshaw of the Museum of Comparative Zoology, Cambridge, Mass., to Mr. Charles W. Johnson of the Boston Society of Natural History, to Dr. Frank D. Adams of McGill University, and to Dr. G. F. Matthew of St. John, N. B., for the highly valued loan of Dr. Jackson's and Sir J. William Dawson's type and other specimens, without which the study of this interesting fauna could not have been properly undertaken.

The Albert shales, primarily held to be of Lower Carboniferous age, principally on the evidence of their fossils, both vegetable and animal, have of late been regarded by some Canadian geologists of repute as properly belonging to the Devonian.

The great similarity of the fauna of the Albert shales of New Brunswick to that of the shales of the Calciferous Sandstone Series of Scotland is clearly apparent from the first to any one studying them and would convince most observers that these fish-bearing beds in the two countries are synchronous and belong to the same horizon. The genera of Palæoniscidæ of the Albert shales of New Brunswick are the same as those of the Scottish shales; the difference is apparent only in the species, and in these there is a remarkable general resemblance. The Calciferous Sandstone Series is held by the Geological Survey of the United Kingdom to form the base of the Car-

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* Quart. Jour. Geol. Soc., vol. ix, p. 115, 1853.

† Palæozoic Fishes of North America, Monographs U. S. Geol. Surv., vol. xvi, p. 187.

‡ Cat. Fossil Fishes British Museum, Part II, 1891.

§ Iowa Geol. Survey, vol. xviii, 1908.

boniferous System in Scotland, and it is the opinion of the writer that the Albert shales should still, as formerly, be regarded as of Lower Carboniferous age.

The fish fauna of the Albert mines and vicinity has been considered for some years to consist of the following species:—*Rhadinichthys alberti* (Jackson), *R. cairnsi* (Jackson), *R. modulus* Dawson, *Elonichthys browni* (Jackson) and *E. jacksoni* (Dawson), and lately Eastman has described a new form of small size under the name *Elonichthys elegantulus* (Iowa Geol. Survey, vol. xviii, 1908).

After a careful study of all available material the writer is forced to the opinion that *R. cairnsi* is not distinct from *R. alberti*, that *E. jacksoni* is the same specifically as *E. browni*, and that *R. modulus* is more properly referable to the genus Canobius of Traquair. The generic position of *E. elegantulus* is considered to be problematical; the small size of this species in conjunction with its generally imperfect state of preservation leads the writer to suspect that it may be the young of one of the species already known from the Albert mines, possibly of *R. alberti*.

This fauna thus appears to consist of the three species *Rhadinichthys alberti*, *Elonichthys browni*, and *Canobius modulus*. To these may be added a fourth regarded as new, belonging to the genus Elonichthys, and for which is proposed the name *E. ellsi*, in honour of Dr. R. W. Ells, who many years ago obtained the type and only known specimen at the Albert mines.

The ornamentation of the scales, more especially of the anterior flank scales, in these species is thoroughly distinctive and is one of the most useful characters available for the determination of poorly or partially preserved specimens or even of scattered scales.

With the following short descriptions of the four above mentioned species are given figures of the anterior flank scales and, in the case of three of them, of the posterior flank scales also.

RHADINICHTHYS ALBERTI (Jackson).

Palæoniscus alberti Jackson, 1851. Report on the Albert Coal Mine, etc., Boston, p. 22, plate I, fig. 1, plate II, figs. 2, 2 bis, 3, 4, 5, 8 and ? 6.

Palæoniscus cairnsii Jackson, 1851. Ibid., plate I, fig. 3.

This species is the first of the Albert mine fishes described by Jackson.

It is of small size, rather slender, fusiform, averaging in length about 8·5^{cm}. Greatest depth of trunk in advance of the pelvic fins, slightly over one-fifth the total length. Head, in length, about equal to the maximum depth of the body. Eye of moderate size, placed far forward. Fins well-developed. Dorsal fin beginning a little behind the mid-length of the fish, triangular, about the same size as, and arising somewhat in advance of, the anal fin. Caudal fin much prolonged in upper lobe, deeply forked. Pectoral fins large, with a short base. Pelvic pair if anything nearer to the anal fin than to the pectorals, of small size. Teeth minute. Suspensorium oblique.

Anterior flank scales, figures 1 and 2, about as deep as long (exposed surface), ornamented with striations, of which about six are fine and parallel to the lower and anterior margins, whilst three or four are coarse and have an oblique backward and downward direction in the upper posterior quarter of the scale. Posterior margin of scales serrated. Posterior flank scales with fewer oblique striæ, the remainder of the exposed surface being smooth; posterior margin with fewer but relatively coarser serrations. Scales of body prolongation of tail diamond-shaped.

Enlarged ridge scales present from near the head to the dorsal fin, and from behind that fin on to and along the upper lobe of the tail. There are also about three similarly enlarged scales in advance of the anal fin, and about the same number between it and the caudal. The enlarged scales are coarsely and irregularly striated longitudinally, longer than broad, narrowly rounded in front and somewhat pointed behind. Fin rays jointed throughout, except the principal anterior ones of the pectoral fins, which appear to be entire proximally. They subdivide distally and have the appearance of being slightly striated in the direction of their length. Minute fulcra are present on the margin of the lower caudal lobe and on the anterior margins of the other fins. The head bones are ornamented with longitudinal ridges and tubercles, and transitions between the two.

The scales of the type specimen of *R. cairnsi* are well preserved with the sculpture particularly definite. The specimen itself is rather larger than the average sized specimens of *R. alberti.* To the writer the striation of the scales appears to be the same in both species, poorly preserved in the type of *R. alberti* but very clearly shown in the type of *R. cairnsi*, with a like serration of the posterior margin in both. Other characters distinguishing the two species are not observed and the conclusion has been reached that there is no real distinction between the two.

ELONICHTHYS BROWNI (Jackson).

Palæoniscus brownii, Jackson 1851. Report on the Albert Coal Mine, etc., Boston, p. 22, plate I, figs. 2 and 5, plate II, fig. 1, and plate I, ? fig. 4.

Palæoniscus brownii and *P. jacksonii* Dawson, 1877. Canadian Naturalist, new series, vol. 8, p. 339.

Palæoniscus (*Elonichthys*) *brownii* and *P. jacksonii* Dawson, 1878. Acadian Geology, 3d edition, supplement, p. 101.

A species of moderately large size, reaching a length of $37{\cdot}5^{cm}$ (about 15 inches). Maximum depth of the trunk, slightly in advance of the pelvic fins, contained about three and three quarters times in the total length. Length of head, including the opercular apparatus, about one-fifth of the total length. Fins rather large. Pectoral fin powerful, spreading, with a restricted base; rays articulated except the first two or three anterior ones proximally. Pelvic fins, small in comparison with the other fins, about midway between the pectoral and anal fins, in advance of the mid-length of the trunk. Anal fin large, triangular, with a broad base, reaching posteriorly close to the tail. Dorsal fin similar in shape to the anal but not quite as large, the center of its base nearly above the anterior end of the base of the anal. Caudal fin large, the body prolongation of the upper lobe robust, extended, the lower lobe well-developed. Fulcra in all the fins conspicuous. External bones of the head ornamented with definite ridges of varying length, straight or slightly tortuous and having a general longitudinal direction, replaced at times by tubercles.

Flank scales near the head (figure 3), sculptured by from sixteen to twenty striations running obliquely backward except in the anterior lower portion of the scale surface where they are parallel to the lower margin. Posterior margin serrated. Usually in passing backward on the trunk, the striæ decrease in number and gradually disappear, being replaced by a few punctations, the surface of the scales becoming smoother and the serrations fewer in number, figure 4, until in the upper lobe of the tail both punctations and serrations are lost, leaving the scales smooth. It is found, however, that the striations of the scales persist in a variable degree, in different specimens, in the posterior half of the trunk, and in some even the caudal scales retain a number of the striæ. Between the dorsal and anal fins the flank scales are nearly twice as long as high with a considerable overlap, but near the head they have more the form of a rhombus. The exposed surface of the anterior flank scales is higher than long.

Enlarged, longitudinally striated, imbricating dorsal ridge scales extend in a row from near the head to the dorsal fin, and from the latter to the extremity of the tail, on the upper lobe of which they are of modified shape and gradually diminishing size. Between the anal fin and the tail similar scales occur. Enlarged, longitudinally striated scales are seen in a number of specimens, between the anal and ventral fins. The more anterior dorsal ridge scales are ovate, slightly longer than broad, becoming more pointed behind on approaching the dorsal fin. The posterior margin is denticulated.

In the fins, the rays are articulated throughout except the most proximal part of the first two or three rays of the pectoral. They subdivide distally, and a second and apparently also a third subdivision may take place, On the front border of the joints, in the more anterior part of the fins, short oblique striations are observed. These particular markings are not observed in the posterior half of the fins, where another style of ornamentation is developed near the base, viz., a minute serration of the hinder border of the joints.

The mandibular suspensorium is apparently oblique. The teeth, as seen imperfectly in one specimen only, seem to be arranged in two rows, after the manner of the genus, viz., with small teeth in an outer row, and larger ones, at intervals, forming an inner row.

The type specimen of Dawson's *Palæoniscus jacksoni* (figure 4 of Jackson's plate I) is not available for study, but judging from the figure, and from Dr. Jackson's remarks on its scale ornamentation, it appears to the writer probable that it is not distant from *E. browni*. A specimen from McGill University museum, labelled *P. jacksoni*, Hillsborough, No. 2698, has the scale sculpture and the ornamentation of the joints of the fin rays such as are seen in Jackson's type of *E. browni* with which it is evidently conspecific. Among the specimens from the Natural History Society of New Brunswick is the original of the one from which the plaster cast, mentioned by Sir William Dawson in his Acadian Geology, was taken, which cast formed part of the material on which *P. jacksoni* was based. The specimen consists of the posterior part of the fish, from slightly in advance of the dorsal fin backward to the end of the tail. The anterior basal portion only of the anal fin is preserved, and the position of the dorsal fin is indicated, but the specimen is elongated by distortion, and both fins are more distant from the tail than they otherwise would be. The general contour of the specimen is much the same as that of others in the collections of the Survey similarly distorted, and the characters of the scales are clearly those of *E. browni*, to which species the specimen is referred.

ELONICHTHYS ELLSI sp nov.

A species of small size. Type and only specimen known about 12^{cm} ($4\frac{3}{4}$ inches long). Greatest depth a little less than one-fourth the length. Head, with opercular apparatus, one-fourth the total length. Dorsal fin large, arising very slightly behind the mid-length of the fish, and but little in advance of the anal fin, which is about the size of the dorsal. Both of these fins are triangular, with a base about equal to the length of the anterior border. Fulcra are apparently present on all the fins; plainly seen on the dorsal and anal fins. Of the ventral and pectoral fins, a few rays only are preserved, which serve as an index to the fins' position. Ventral fins rather closer to the anal than to the pectoral fins. The fin-rays are articulated, except the principal ones of the pectoral fins, which are entire, at least, proximally; they are finely striated in the direction of their length. The tail is deeply forked. Scales of moderate size; about as deep as broad on the flank anteriorly, figure 5, where they are ornamented with nine or ten conspicuous, narrow ridges, directed backward and deeply serrating the posterior border. Posterior flank scales, figure 6, less highly ornate, and with few but well-marked serrations posteriorly. Scales of the caudal body prolongation nearly smooth. Enlarged scales extend along the dorsal ridge in a row, in advance of the dorsal fin, to the head, and behind the same fin backward to the termination of the upper lobe of the tail. Similarly enlarged scales occur between the anal fin and the lower lobe of the tail, with a few, probably three or four, in front of the anal fin. Head-bones marked by irregular, short ridges, and tubercles. Suspensorium apparently oblique.

The ridges of enamel on the anterior flank scales constitute the most conspicuous feature of the scale ornamentation of this species. These ridges, nine or ten in number, are mainly developed on the posterior half of the scale, and have the appearance of rows of connected tubercles. A few fine striæ occur near and parallel to the lower margin of the scales.

The enlarged ridge scales are rugosely and irregularly striated longitudinally, and are toothed behind. Conspicuous horizontal striations or linear depressions occur in the modified scales of the caudal ridge.

The most distinctive character of the species is the style of ornamentation of the anterior flank scales, which is different from that of any other of the Albert shales fishes, and, so far as the writer is aware, from that of any species of the Palæoniscidæ.

The species is named after Dr. R. W. Ells, to whom we are indebted for the one and only specimen known. This specimen constitutes the type of the species.

CANOBIUS MODULUS (Dawson).

Palæoniscus (*Rhadinichthys*) *modulus* Dawson 1877. Canadian Naturalist, new series, vol. viii, p. 338, figs. *a–d;* and 1878, Acadian Geology, 3d edition, supplement, p. 98, figs. 18*a–d.*

This fish is short and robust, the mandibular suspensorium is apparently nearly vertical, the head is blunt in front, and enlarged ridge scales, in a row, pass backward from the occiput to the dorsal fin and occur again in advance of the caudal fin. These characters suggest its being referable to Traquair's genus *Canobius* rather than to *Rhadinichthys*, to which genus it was assigned when first described.

It reaches a length of 59^{mm} with a depth in advance of the dorsal fin of 15^{mm}. The length of the head, including the opercular apparatus, is a little less than one-fourth of the total length. The snout is rounded and projects beyond the lower jaw. The orbit is large and placed far forward. The bones of the head are ornamented with well-defined, short vermicular ridges, and tubercles, the former being generally in the direction of the bone. The mandibular suspensorium is nearly vertical and thus differs from that of *Rhadinichthys*, which is oblique. The dorsal and ventral fins are triangular and of fair size, the former slightly larger than the latter. The dermal rays are delicate and seem to bifurcate distally; they are articulated, with the exception of the principal ones of the pectoral fins, which apparently are not articulated, at least proximally. Fulcra occur on all the fins. The anal fin is opposite the dorsal, and the ventral pair is slightly closer to the anal than to

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EXPLANATION OF FIGURES.

FIGURE 1. *Rhadinichthys alberti*, anterior flank scales from a specimen from the Albert mines, in the collection of the Geological Survey ; eight times the natural size.

FIGURE 2. *Rhadinichthys alberti*, anterior flank scales from the type of *R. cairnsi ;* similarly enlarged.

FIGURE 3. *Elonichthys browni*, flank scales, from two rows next above the lateral line, midway between the head and the dorsal fin, in the type specimen ; six times the natural size.

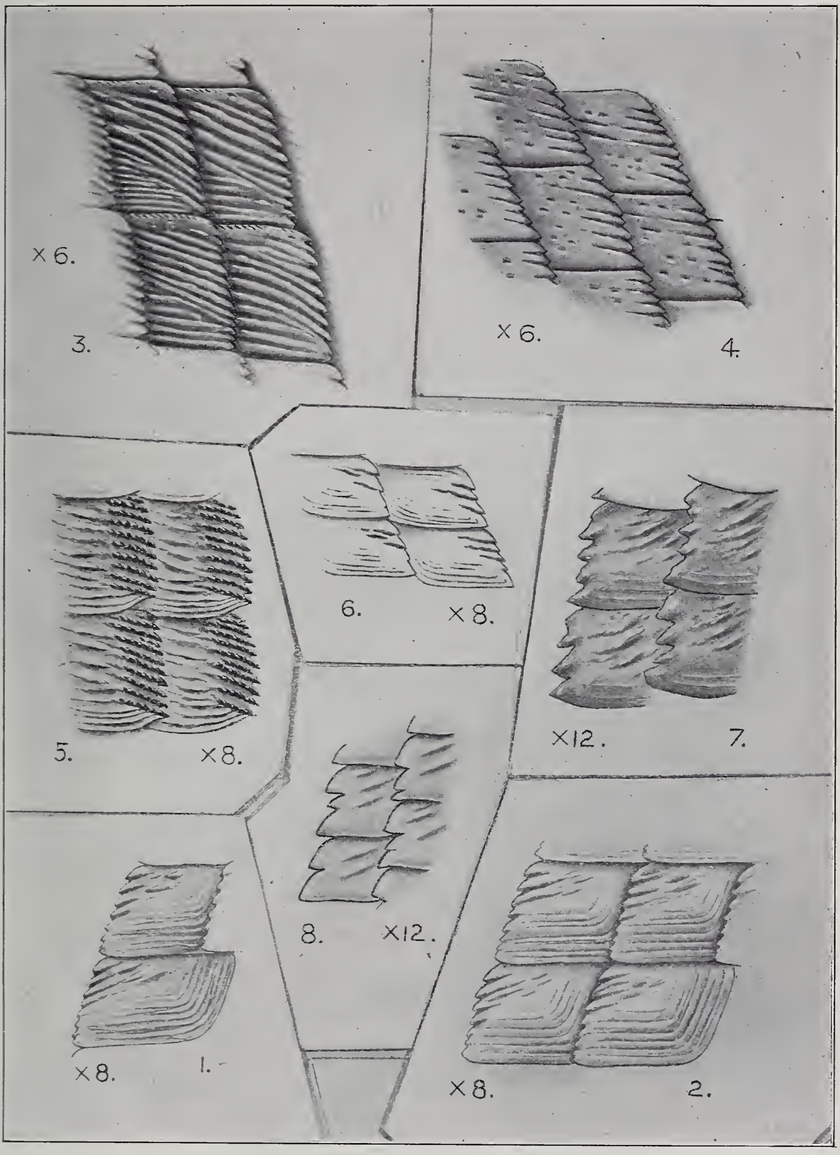
FIGURE 4. *Elonichthys browni*, flank scales next above those of the lateral line, beneath the front end of the dorsal fin in the type specimen ; six times the natural size.

FIGURE 5. *Elonichthys ellsi*, anterior flank scales from the type specimen ; enlarged eight times.

FIGURE 6. *Elonichthys ellsi*, posterior flank scales, from a little above the mid-height of the body in line with the back part of the dorsal fin ; similarly enlarged.

FIGURE 7. *Canobius modulus*, anterior flank scales, from the two rows beneath the lateral line scales, in the type specimen from Beliveau, N. B.; twelve times the natural size.

FIGURE 8. *Canobius modulus*, posterior flank scales, beneath those of the lateral line, in the type specimen ; similarly enlarged.



Palæoniscidæ.

the pectorals. The caudal fin is heterocercal and deeply forked, the body prolongation in the upper lobe tapering gradually. The scales are rather coarsely sculptured. In the anterior flank scales, figure 7, the sculpture consists of two or three delicate but distinct well-defined ridges in the lower half of the surface, parallel to the lower margin, with three to five short, prominent ridges in the upper half of the scale; these latter are directed obliquely backward and downward in a somewhat divergent manner from a slightly raised but ill-defined area confined to the upper, anterior portion of the scale. The posterior edges of the flank scales are coarsely toothed, three or four being the usual number of the denticulations. In passing backward the surface ridges of the scales, figure 8, are reduced in number as are also the denticulations of the posterior margins, until posteriorly, in the small diamond-shaped scales of the caudal body prolongation, all trace of sculpture is lost and the surface of each scale is smooth. Enlarged, ovoid, imbricating scales, with well-marked longitudinal ridges, extend along the median line of the back, in a single row, from the head to the commencement of the dorsal fin, and from behind this fin to the caudal, on which they are continued as large fulcra-like modifications decreasing in size posteriorly. On the ventral surface similar enlarged scales occur between the ventral and anal fins and between the latter and the base of the caudal, where they give place to small fulcra on the lower margin of the tail. Of the flank scales the largest are those of the lateral line.

Two specimens from Beliveau, N. B., of which one is the type, and one specimen from Horton, N. S., constitute the type material of this species.

Canobius modulus has about the same length as *C. ramsayi* Traquair but is not so deep. The scales are differently sculptured and in this respect the species is distinct from all other described ones of the genus.

Art. XIX.—*Diatomaceous Dust on the Bering Sea Ice Floes**; by E. M. Kindle.

In ordinary seasons the winter's accumulation of ice in Bering Sea disappears to a sufficient extent by the end of the first week in June to offer no serious obstacle to navigation. The ice conditions during the spring and early summer of 1908 in Bering Sea were very unusual, however, and all of the steamers sailing for Nome in June were imprisoned for brief periods in the Bering Sea ice packs. Most of the vessels occupied from 8 to 10 days in working through the 300 miles of ice floes which lay between the Seward Peninsula and the open water in the southern part of Bering Sea. The steamer Umatilla, on which the writer was a passenger, first encountered the ice pack off the southwest coast of Nunivak Island, June 11, in scattering cakes. During the succeeding eight days, which the vessel spent among the ice floes, the opportunities were favorable for observing the character of the materials appearing upon the surface of the ice and for collecting samples of the dirt on the floes.

At the time of the writer's observations the long-continued attrition of the ice cakes comprising the floes had broken them into pieces generally not exceeding 200 feet in diameter. A few cakes much larger than this still remained, however, and one was observed with a length of not less than 350 yards.

A very large percentage of the ice cakes were more or less discolored by dirt or dust. Probably 80 per cent of the ice bore small amounts of fine dust or dirt in sufficient quantity to give it a slight gray or blackish color in spots. No pebbles or rocks of any kind were observed on the floes. The very fine texture of the dirt together with its dissemination through the snow on the ice suggest that most of it reached the surface of the ice through transportation by the wind. This fine material was observed to show a strong tendency to segregate itself into little pellets as the melting of the snow and ice containing the dirt proceeds. These ranged in size from bird shot up to the size of peas. They were nearly or quite spherical and in the case of the larger ones sufficiently firm and compact to probably reach the bottom without dissolution on the complete melting of the ice in shallow water like that of the northern half of Bering Sea.

The color of the dust seen on the ice was generally gray, dark brownish or black. A sample of the black dust which was examined by Mr. A. Knopf at the writer's request is stated by Mr. Knopf to be unquestionably of volcanic origin. It may represent a fall of volcanic dust which occurred Novem-

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* Published by permission of the Director of the U. S. Geol. Survey.

ber 2, 1907, and covered an extensive area in northwestern Alaska, including the greater part of the Seward Peninsula. Samples of the gray dust show very fine-textured earthy material of about the same degree of coarseness as is seen ordinarily in the loess.

An interesting feature of these samples of ice-borne dust is the presence in most of them of considerable numbers of marine diatoms. These organisms are quite as abundant in the dust sample which is chiefly of volcanic origin as in the gray non-volcanic dust. Through the kindness of Dr. Albert Mann, the writer is able to present a list of the species which were found in the samples collected. These were obtained from the ice floes about 30 miles northwest of Cape Romanzof.

The list which follows gives the species which were recognized by Dr. Mann:

List of Diatoms from Ice Floes; by Albert Mann.

"I find the dust collected on ice-floes in Bering Sea to be fairly rich in diatoms. Below are the species found therein:

Coscinodiscus radiatus Ehrenb.
Coscinodiscus subtitis Ehrenb.
Coscinodiscus curvatulus Grun.
Coscinodiscus excentricus Ehrenb.
Coscinodiscus lineatus Ehrenb.
Coscinodiscus robustus Grev.
Coscinodiscus spec?
Coscinodiscus pustulatus Mann.
Biddulphia aurita (Lung.) Breb. & God.
Melosira sulcata (Ehrwnb.) Kutz.
Actinoptychus undulatus
Navicula brasiliensis Grun.
Navicula fontinalis Grun.
Coscinodiscus apiculatus Ehrenb.
Gyrosigma thuringicum (K.) Rab. See Wm. Smith's Synop. Brit. Diatoms; Vol. I; Pl. 21; Fig. 205; p. 65. Mann, Diat. Albatross Voyages: p. 366.

"This last species should retain its well known name *Pleurosigma angulatum* W. Sm.

"The first named species, *C. Radiatus*, is by far the most common. It may be of interest to note that the above species were found by me in the dredgings of the S. S. Albatross, made in the southern part of Bering Sea, mostly at considerable depths. The new species, *C. Pustulatus*, Mann, was found at a depth of over 1800 fathoms.

"*Coscinodiscus* spec? is an unnamed species. I found this also in the Bering Sea dredgings and mentioned it in my report as *C. Heteroporus*, Ehrenb. The specimen I marked as doubtful. I find several examples of it in these samples and am able to recognize it as identical with the imperfect valve I found in the Albatross material."

Diatoms have not been observed before on the Bering Sea ice and the recorded occurrences of these organisms on floating ice elsewhere are not numerous. The careful observations of Nansen* have shown, however, that the presence of diatoms on the circumpolar ice packs is not an unusual or accidental circumstance, as was formerly supposed. Many species of diatoms were found by Nansen, during the drift of the Fram, to be living in the shallow pools of water on the surface of the floating ice cakes. Vanhoffen † found on the west Greenland

FIG. 1.

FIG. 1. View of an ice cake showing discoloration of front and left sides by diatomaceous dirt, with pool of fresh water in the center.

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* Fridtjof Nansen, the Norwegian North Polar Expedition, 1893-1896, Scientific Results, Protozoa on the ice floes of the North Polar sea, vol. v, pp. 5–6, 1906.

† The Norwegian North Polar Expedition, 1893–1896, Scientific Results, vol. iv, 1904, p. 8.

coast that diatoms resort to the under surface of the ice in abundance and are able to live there.

The abundance of diatoms in all of the samples of dirt collected from the Bering Sea ice suggests that the normal habitat of some of the species obtained for part of the year is the shallow ponds of fresh or brackish water on the ice cakes. One of the pools from the margin of which diatom-bearing dirt was obtained is shown in the photograph, fig. 1. Some of the species may attach themselves to the under surface of the ice as observed by Vanhoffen in the early winter while it is thin, become frozen in and reach the upper surface by the melting of the upper layer of the ice in early summer.

The siliceous tests of these minute plants comprise an important component of the fine-textured sediments which the annual melting of the Bering Sea floes is sifting down on the sea bottom.

The nearest locality to Bering Sea from which diatoms have been found on floe ice is near Cape Wankarema, west of Bering Strait about 200 miles.

Comparison of the species in the dirt from Bering Sea ice with those collected from the ice floes near Cape Wankarema by Kjellman of the Vega expedition and by Nansen during the drift of the Fram affords some interesting data on the relationship of floras found on the ice in the Arctic Ocean and in the Bering Sea. But one species, *Coscinodiscus curvatulus*, is common to the Bering Sea diatoms from the ice near Cape Romanzof, and those collected by Kjellman and Nansen in the Polar basin; nine species of the Bering Sea ice flora occur in the Pacific south of Bering Sea; two are found in the southern part of Bering Sea; one, *Navicula fontinalis*, is not recorded from the Pacific by Mann.*

It is thus seen that the affinity of this ice diatom flora is very decidedly with that of the Pacific flora to the south and not at all with that of the Polar sea. This is especially significant when it is recalled that the diatom fauna of Cape Wankarema, which is only about 400 miles from Cape Romanzof, bears the closest resemblance to the diatom fauna of the east coast of Greenland. The identity of the large number of species from the two localities was an important part of the evidence which led Nansen to formulate the theory of ice drift across the Polar basin from the Siberian toward the Greenland coast, which his journey afterwards demonstrated to be true. The two samples of mud collected by Nansen from the floe ice east of Greenland during his expedition to Green-

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* Albert Mann, Report on the Diatoms of Albatross voyages in the Pacific Ocean, 1888–1904. Contr. from the U. S. Nat. Herbarium, vol. x, pt. 5, pp. 225–419, pls. 44–54.

land in 1889 contained 16 species of diatoms, 12 of which were known elsewhere only from floes at Cape Wankarema.*

In contrast with this remarkable resemblance between the Wankarema and the E. Greenland diatom floras which are separated by the entire breadth of the Arctic Sea, we find between the Wankarema and Bering Sea floras almost complete unlikeness, there being but one species common to both. This sharp contrast between the diatom floras occurring on the ice to the northwest and to the south of Bering Strait affords convincing evidence that no definite marine current connects the two areas which could carry the Wankarema flora southward or the Bering Sea flora northwestward. On the other hand, the close resemblance of the Bering Sea ice diatoms to the Pacific flora which is shown by more than nine species common to the two, indicates a close relationship through marine currents with the Pacific Ocean.

Dall's conclusions regarding the movement of water in the southern part of Bering Sea corresponds with the evidence of the diatoms in this respect. He states :† "My own conclusion from a study of the data is that the general tendency of the water in Bering Sea is to the southward and where deep enough as in the western part of the sea it forms a tolerably well defined current." The ice drift in the vicinity of Cape Wankarema, on the other hand, was shown by the drift of the Jeannette to be to the northward or away from Bering Strait. These opposite tendencies of the currents in the two areas explain the contrast between the diatoms of Cape Wankarema and Cape Romanzof.

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* H. H. Gran, Diatomaceæ from the ice floes and of the Arctic Ocean: The Norwegian N. Polar Exped., 1893–96, vol. iv, p. 6, 1904.

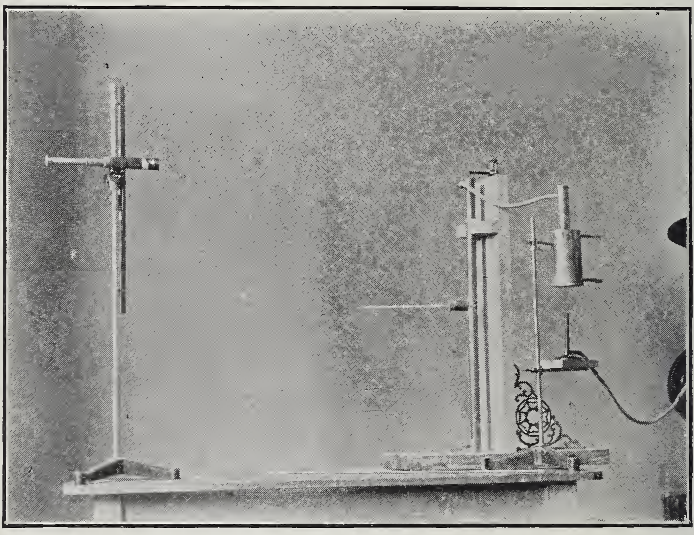
† Report U. S. Coast and Geodetic Survey for 1880. Appendix No. 16, p. 315.

Art. XX.—*A Modification of Lavoisier and Laplace's Method of Determining the Linear Coefficient of Expansion*; by S. R. Williams.

A General Laboratory Method.

The first accurate determinations of the Linear Expansion Coefficients of solids were made by Lavoisier and Laplace* in 1782. The rods, whose change in length with temperature they investigated, were placed in a water-bath with one end clamped firmly against a rigid wall, while the other end was fastened to a lever which rotated a telescope about a horizontal axis. The telescope was directed toward a vertical scale and from the deflections the changes in length were determined as the temperature of the bath was varied from 0° to 100° C.

Fig. 1.



In the following I wish to describe a simple modification of Lavoisier and Laplace's method which overcomes several difficulties encountered in that of the original as well as in the numerous devices now used for this experiment.

Figure 1 shows the apparatus as used in the laboratory, and figure 2 shows it schematically. The steam-jacket, A, encloses the rod, R, whose change in length is to be studied.

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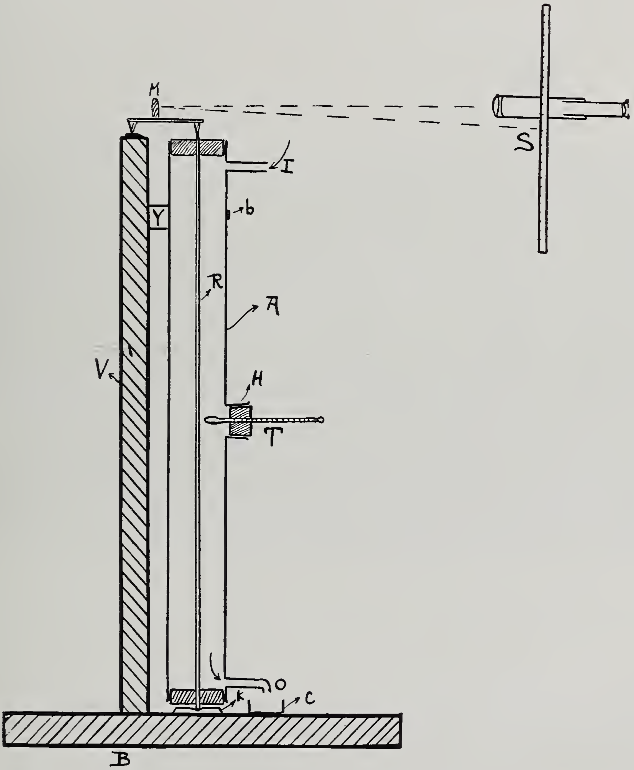
* Lavoisier and Laplace, Bot. Traite de Physique, vol. i, p. 151.

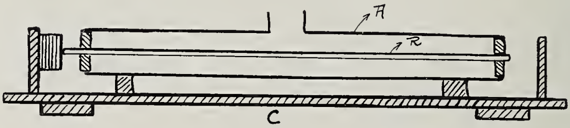
As will be noted, the essential difference between this arrangement and that of Lavoisier and Laplace is that the steam-jacket and rod are here arranged in a vertical position. A small rubber band at *b* holds the tube, A, lightly against the Y opening at Y. By means of corks in the ends of the tube, particularly the lower one, the steam-jacket is supported on the rod, R, which in turn rests on its end in a depression in K. This insures that the lower end of the rod will always remain in a fixed position without the necessity of clamping it, and prevents the tube from creeping due to its own expansion. In some five or six devices for measuring the linear coefficients in which the steam-jacket rested in a horizontal position in Y's, as in figure 3, I have found that the tube creeping carried the bar along with it; this is usually overlooked by the student and the results obtained are very discordant.

Fig. 2.



K is a thin strip of brass with a small depression in which the lower end of the rod rests. In one type of expansion apparatus this block, against which one end of the rod was placed, was about two inches long, and its expansion from the heat of the rod was quite appreciable. H is an opening in the side of the tube with a cork through which the thermometer, T, is thrust. The base, B, was made from a plank 2×10×24 inches, and the back support, V, was 2×8×31 inches. This stand was made heavy in order that any heating effects from the steam-jacket would not warp or distort it during the experiment. In figure 3 is shown the usual support for the steam-jacket, in a horizontal position, which is either of thin boards or a metal bar. A slight pressure at C will change the readings altogether, or if the upper side of the base, whether wood or metal, is at a different temperature from the lower the same results will occur. The optical lever for measuring changes in length has been adhered to because it admits of great accuracy and yet is simple.

Fig. 3.



The method of focusing the cross wires of two microscopes on the ends of the bar and then by means of micrometer eyepieces measuring the changes in length is used by the International Bureau of Weights and Measures, and is very accurate, but for high school laboratories it is too elaborate, and for the average college is rather expensive. None of the common methods, as the electric contact, the vernier micrometer and the wooden lever, are as precise as the two mentioned above.

The vertical position of the steam-jacket and rod makes the use of the optical lever a convenient one, since the back, V, can be made the same height as the rod, and with the mirror, M, on a tripod bridging across from V to R, the telescope and scale, S, can be put in a convenient position for observations.

I and O are the openings for the passage of steam through the steam-jacket. In the general laboratory we have taken the length of the bar at room temperature and then again at the temperature of steam, but the apparatus may be very easily adapted to the circulation of water in the steam-jacket and so the lengths for intermediate temperatures may be obtained.

This apparatus has been in use for two years in the general laboratory, and I have found that the students have reported very concordant results. Its simplicity makes its construction possible with a very limited supply of tools and means.

Physics Laboratory, Oberlin College, May 12, 1909.

Art. XXI.—*A New Proboscidean from the Lower Miocene of Nebraska;* by Harold James Cook.

* *Gomphotherium conodon* sp. nov.

In the collections of the writer are two broken teeth (No. HC 176) found in the summer of 1906 in the lower part of the Upper Harrison beds, near Agate, Sioux County, Nebraska. Although averse to founding new species on fragmentary material, the type here represented seems quite important, and as the Upper Harrison beds have been vigorously searched by several parties during the past three years and no other evidence of this unexpected form has been secured, a description is here given.

Fig. 1.

The teeth are unworn, and may be a part of the milk dentition, but are quite different from any described species. They are simple bunodont teeth, with a very heavy crinkled cingulum, which tends to develop into cusps as in other proboscideans. Though apparently somewhat more robust, the teeth are essentially more simple than those of *Palæomastodon*. They have only a slight roughness on the sides of the cusps, where *Palæomastodon* has a distinct tendency toward a crest. The tubercles or cusps are relatively low and blunt, much like those of the Eocene proboscideans. The enamel is very much thinner than in any known American type.

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* *Gomphotherium* Burmeister, 1837 = *Tetrabelodon* Cope, 1884.

Although the specimen is provisionally referred to the genus *Gomphotherium*, it probably represents an undescribed genus, and may be a persistent primitive type.

It does not agree with any known type of *Entelodon* in that the cingulum is very much heavier and crinkled, *developing distinct cusps*. Though it is impossible to state the exact molar tooth-pattern, owing to the fragmentary condition of the specimen, one tooth shows a particularly well-developed cusp on the cingulum, about one-fourth of an inch in height.

As it is an unexpected type from these beds, a word as to its occurrence may be in order. There can be no question as to its belonging to the Upper Harrison beds, as a part of one tooth was found in the matrix. In the light of the latest discoveries in these beds, they appear to represent a phase of the Lower Miocene.

The writer is indebted to Prof. Charles Schuchert and Prof. R. S. Lull of Yale, also Prof. H. F. Osborn and Dr. W. D. Matthew of the American Museum of Natural History, for assistance rendered in the study of this type.

American Museum of Natural History,
New York, Dec. 12, 1908.

ART. XXII.—*Mineral Notes from the Mineralogical Laboratory of the Sheffield Scientific School of Yale University.*

1. *Calamine Crystals from the Organ Mts., Donna Anna Co., N. M.;* by W. E. FORD and FREEMAN WARD.

DURING the past year several specimens of calamine from the Organ Mts., Donna Anna Co., New Mexico, have been acquired by the Brush Mineral Collection. These specimens show distinct and separate crystals of unusual size and quality for calamine, resembling in appearance and character the crystals from Altenberg, Belgium. Because of the rarity of such occurrences of the mineral it was considered worth while to measure and figure these crystals and to call attention to the occurrence by a note. Unexpectedly the study revealed the presence of a form apparently new to the species.

FIG. 1.

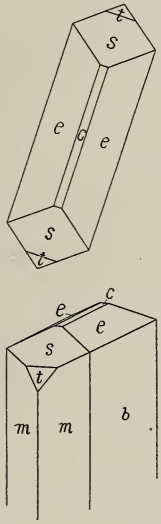
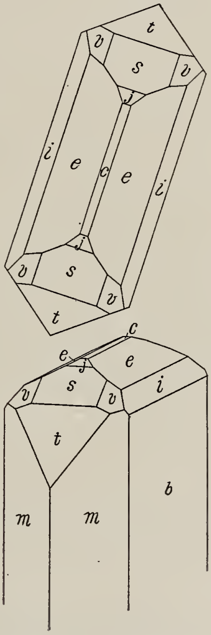


FIG. 2.



The crystals are clear and colorless with a tabular development parallel to *b* (010), and average about 1^{cm} by 5^{mm} for their largest dimensions. The forms identified upon them were as follows : *b*(010), *c*(001), *m*(110), *j* (407)*, *s*(101), *t*(301),

e(011), i(031), v(121). The crystals were all attached and no faces terminating the antilogous poles were observed. They were usually developed as shown in figure 1, while the pyramid v, the brachydome i and the new macrodome j, were only observed on a few crystals, and then but as small truncations, as is shown in figure 2. The new form j (407) occurred as very small but definite-shaped faces, which did not yield very sharp reflections. No other simple indices would satisfy the angle measured, and it is thought, therefore, that the identity of the form is reasonably well established. The measured angle of $c(001) \wedge j(407)$ was 19°+, the calculated angle being 19° 12′ 45″.

Fig. 3.

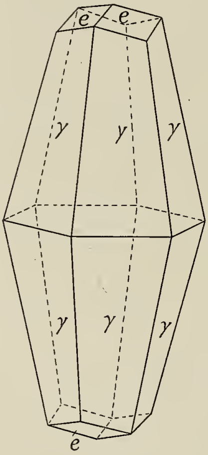
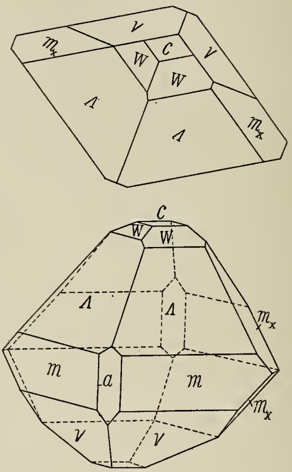


Fig. 4.



2. *Calcite Crystals from Kelly's Island, Lake Erie*;* by W. E. Ford and J. L. Pogue.

Recently, through Mr. Lazard Cahn, the Brush Collection received some calcite crystals from Kelly's Island, Lake Erie, which were remarkable in that the prominent form upon them was the rare pyramid, $\gamma(8\cdot8\cdot\overline{16}\cdot3)$. The pyramid exists on the crystals alone with the exception of a rounded rhombohedral termination which was assumed to be $e(01\bar{1}2)$. The measured angles which identified the pyramid form were, $(8\cdot8\cdot\overline{16}\cdot3) \wedge (8\cdot8\cdot$

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* The form $\gamma(8\cdot8\cdot\overline{16}\cdot3)$ has been noted as a prominent form on crystals from Bellevue, Ohio. Farrington and Tillotson, Field Columbian Museum, Geol. Series, iii, No. 7, 144, 1908.

$\bar{1}\bar{6}\cdot\bar{3}$) = 24° 42′ and 24° 48′ agreeing closely with the calculated value of 24° 46′. This pyramid was first noted by vom Rath* on crystals from Andreasberg in the Harz; and has been noted on crystals from Union Springs, Cayuga County, N. Y., by Penfield and Ford,† but never so far, as the writers know, has it been found so largely and simply developed, as in this instance. The crystals are honey-yellow in color, and average from 3 to 4^{cm} in length and from 1 to $1\cdot5^{cm}$ in greatest diameter.

3. *Crystals of Datolite from Bergen Hill, N. J.;* by W. E. Ford and J. L. Pogue.

A short time ago Prof. E. S. Dana received from Mr. James G. Manchester of New York City a small suite of unusally perfect and symmetrical datolite crystals, which being shown to the present writers seemed worthy of a brief description. They were found lying loose in sandy material at the bottom of the open cut which is at present being put through the trap ridge at Bergen Hill by the Erie railroad. Most of the crystals were completely and symmetrically developed, and showed no evidence of previous attachment to other minerals or a rock surface. In one specimen the small crystals of datolite were seen lying in the angles between interpenetrating rhombohedrons of calcite, and in another they were associated with an asbestiform mineral and minute crystals of apophyllite. The crystals were all of them small, the largest of the suite shown in its true proportion and development in figure 4 being 8^{mm} in its greatest diameter. Many of the crystals were much smaller. They are colorless, perfectly transparent, and their faces have a brilliant luster. But of chief interest is the almost ideally symmetrical development which they possess, a thing of considerable rarity among datolite crystals. The forms identified, all of which are common, were as follows: a(100), c(001), m(110), m_x(011), W(114), Λ(112), V(111).

Mineralogical Laboratory of the Sheffield Scientific School of
Yale University, New Haven, Conn., July 1, 1909.

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*Pogg. Annalen, cxxxii, p. 521, 1867.

† This Journal, x, 237, 1900.

SCIENTIFIC INTELLIGENCE.

I. Geology.

1. *The Tidal and Other Problems—Contributions to Cosmogony and the Fundamental Problems of Geology;* by T. C. Chamberlin, F. R. Moulton, C. S. Slichter, W. D. MacMillan, Arthur C. Lunn and Julius Stieglitz. Pp. 264. Washington, D. C., 1909. (Published by the Carnegie Institution of Washington.)—In the department of science to which they relate, this series of papers will doubtless take rank among the most important ever published. Not a little of their value is due to the fact that the plans of the investigations have been controlled by a leading geologist on the one hand and a master of celestial mechanics on the other, while many of the detailed problems have been handled by men who were specialists in the respective lines of research involved. By this collaboration the premises and results have been checked with the known details of earth history and celestial relations, and a greater degree of reliance reached in regard to the methods of investigation which were employed. Within the limits of this review, only the more important conclusions can be given, and it is hoped that the result will be to produce a wider study of the volume itself. The first large subject treated under six papers is that of the tidal problem with its bearings on the former rate of the earth's rotation, its influence on the modes of crustal deformation, the initial relations of the earth and moon, and also the problem of the origin of binary stars through fission.

The opening paper is by Chamberlin, and in an introductory portion he gives a synopsis of previous work, followed by a rediscussion of tidal phenomena. The geological evidences are also considered, this topic being treated along the lines followed in Chamberlin and Salisbury's geology. His conclusion is that:

"The application of the most radical and the most rigorous method of estimating the frictional value of the present water-tides, a method which brings to bear practically all the friction of these tides as a retardative agency, irrespective of their positions or directions of motion, seems to show that they have only a negligible effect on the earth's rotation.

"From the best available evidence I conclude that the tides of the lithosphere are chiefly elastic strains and have little retardative value, while the tides of the atmosphere are too small to be measured.

"The accelerative influences seem to be also negligible, so far as geological applications are concerned.

"In close accord with these deductions, the geological evidences indicate that there has been no such change in the rate of the earth's rotation during its known history as to require it to be seriously considered in the study of the earth's deformations" (p. 59).

The quantitative portions of the paper rest upon one on "*The Rotation Period of a Heterogeneous Spheroid*," by C. S. Slichter, and another "*On the Loss of Energy by Friction of the Tides*," by William D. MacMillan. The latter uses the formulæ employed by engineers for the loss of head due to friction and viscosity, and applies them to the ocean. His conclusion is that the day would be lengthened by one second in about 500,000 years. Even if this figure be in error tenfold or a hundredfold it is still in great contrast with the conclusion of Adams in the middle of the last century, that the earth was losing time at the rate of 22 seconds per century, a figure raised to 23·4 seconds by Darwin and lowered to 8·3 seconds by Newcomb.

As Chamberlin points out, these figures have been derived from a secular acceleration of the moon's mean motion, and until a perfect lunar theory is developed such a small irregularity cannot safely be used for the foundation of a superstructure reaching backward tens of millions of years. It is seen that MacMillan's work supports on an entirely independent line of evidence the previous conclusion that no appreciable change in the rate of earth rotation has occurred during the intervals of time assigned by geologists for the portion of earth history recorded in the sedimentary formations.

The next paper is by F. R. Moulton, "*On Certain Relations among the Possible Changes in the Motions of Mutually Attracting Spheres when Disturbed by Tidal Interactions.*" This deals with the general problem of tidal evolution with applications to the earth-moon system. The author first shows that less critical minds than Darwin's have drawn more definite conclusions from Darwin's work than he himself drew. He next states :

"In questions of cosmogony, where immense intervals of time are involved, the problem of tidal evolution is obviously one of great importance, unless it shall some time be shown that it is not a sensibly efficient factor. The two most obvious methods of determining its efficiency are by direct attacks from the mathematical standpoint, or by comparing its certain implications with as many facts given by observation as possible. The first is mainly the method of Darwin, and he has written what will certainly always be an extremely important chapter in the question when considered in the broadest possible way." * * *

"The second method, that of comparing the positive implications of the tidal theory with observed facts in as extended a way as possible, is, broadly speaking, that adopted in this paper" (p. 83).

At the end of the paper Moulton gives a summary, from which the following abstracts are taken :

"The object of this investigation has been to examine the theory of tidal evolution in order to find out, if possible, not what might take place under certain assumed conditions, but how important this process has been in the actual development of our system. The aim has been to avoid, as far as possible, assumptions regarding the uncertain factors depending upon the physical conditions of the bodies involved. In order to compare the theory with the actual facts the various methods of testing it have been carried to quantitative results." * * *

"One of the conclusions reached by Darwin was that it is probable that the earth and moon have developed from an original mass by fission. One critical test of this hypothesis is the determination of the smallest distance at which the bodies could have revolved around each other consistently with the present moment of momentum and energy. This test has been worked out quantitatively, first with the problem simplified so that the conclusions are absolutely certain under the hypotheses; then the effects of various modifying conditions, which seem more or less probable, have been examined, one after another, and their influence upon the final result determined" (p. 127).

It is found that, under the simplified conditions:

"The month has always been increasing and that it cannot pass beyond 47·7 of our present days, at which period the month and day will be equal and the system move as a rigid body. There is no way of telling by this investigation how long a time will be required for the system to reach that state. But it is a more interesting fact that the month can never have been less than 4·93 of our present hours, this being the period of revolution when the distance from the center of the earth to the center of the moon was 9,194 miles. Consequently we must suppose that when the moon broke off from the earth it was at this distance from it, or 5,236 miles from its present surface. Or, including the radius of the moon and supposing that both the earth and moon were of the same density and shape as at present, the distance from the surface of one body to the surface of the other was immediately after fission 4,155 miles. Since this result is altogether incompatible with the obvious implications of the fission theory, we must either abandon the theory or show that this number would be very largely reduced by including the effects of the neglected factors. Consequently we examine the effects of various neglected conditions and influences" (pp. 128, 129).

As a result

"It is seen that the one factor which makes the moon's initial distance less than that found in the first computation is not only of no particular consequence, but also that it is less than some of the factors which increase it. Using all those factors whose effects have been computed when they have been supposed to act separately, and supposing that they would be essentially the same when acting jointly, we find that the smallest possible distance of the moon compatible with present conditions is 9,241 miles."

* * *

" As a concession to the theory, we may assume that the earth and moon have separated by fission so that their periods of rotation and revolution are precisely equal, and then inquire whether the present system could develop from it. If the original orbit were exactly circular the orbit would always remain circular. Since the moon's orbit now has considerable eccentricity it follows that we must assume that the orbit immediately after separation was somewhat eccentric. But since the rotations would be sensibly uniform while the revolution would be such as to fulfil the law of areas, there would be relative motion of the various parts and therefore tidal evolution. The question whether this friction would drive the moon farther from the earth or bring it back and precipitate it again upon the earth is treated in section X, and it is found there, under the assumption that the loss of energy is proportional to the square of the tide-raising force and the square of the velocity of the tide along the surface of the earth, that *the tides would bring the moon again to the earth.* Thus, unless some of the neglected factors can offset this result, the direct implications of the theory destroy it, and it may be noted here that these remarks apply with equal force to the hypothesis that the binary stars have originated by fission and that their present distances from each other and the eccentricities of their orbits are a result of tidal friction " (pp. 130, 131).

"It is well known that a comparison of ancient and modern eclipses shows that the moon has an acceleration in longitude of about 4″ per century which is not explained by perturbations. Let us assume that this is due to tidal friction and is the measure of it at the present time. At this rate it will take over 30,000,000 years for the moon to gain one revolution. Consequently we see without any computation that it must have been an extremely long time in the past when its period was a small fraction of its present period.

" The problem was treated in section XV, and it was found there that, if the physical condition of the earth has been essentially constant, the length of the day was 20 of our present hours, and of the month 24 of our present days, not less than 220,000,000,000 years ago. It is extremely improbable that the neglected factors, such as the eccentricity of the moon's orbit, could change these figures enough to be of any consequence. This remarkable result has the great merit of resting upon but few assumptions and in depending for its quantitative character upon the actual observations. If it is accepted as being correct as to its general order, it shows that tidal evolution has not affected the rotation of the earth much in the period during which the earth has heretofore been supposed to have existed even by those who have been most extravagant in their demands for time. And if one does not accept these results as to their general quantitative order, he faces the embarrassing problem of bringing his ideas into harmony with the observations" (p. 132).

"In a word, the quantitative results obtained in this paper are on the whole strongly adverse to the theory that the earth and moon have developed by fission from an original mass, and that tidal friction has been an important factor in their evolution. Indeed, they are so uniformly contradictory to its implications as to bring it into serious question, if not to compel us to cease to consider it as even a possibility" (p. 133).

Moulton's results, based mostly upon the fundamental equations of moment of momentum and energy of the earth-moon system, are thus seen to be an independent proof in harmony with the two preceding, that no changes of importance in the rate of earth rotation have taken place within the period of known earth history, going, however, still further, and pointing to their always having been separate masses.

The next paper consists of "*Notes on the Possibility of Fission of a Contracting Rotating Fluid Mass*," by F. R. Moulton. In the summary at the end of the paper it is stated :

"The problem under consideration is that of the fission of celestial bodies because of rapid rotation when they are not disturbed by important external forces. The attack is made through well-known results concerning the figures of equilibrium and conditions as to stability of rotating homogeneous incompressible fluids. It is recalled that for slow rotation a nearly spherical oblate spheroid is a stable form of equilibrium ; that for greater rates of rotation the corresponding figure is more oblate ; that when the eccentricity of a meridian section becomes 0·813 the figure loses its stability and at this point a stable line of three-axis ellipsoids branches ; that when the longest axis of the ellipsoid becomes about three times the axis of rotation a new series, known as the pear-shaped figures (or better, perhaps, the cucumber-shaped figures) branches, and that before this point is reached there is no possibility of fission. We are almost entirely ignorant as to what may happen after this point is passed, and it must be remembered that it has not been proved that in any case fission into two stable bodies is possible.

"The celestial bodies differ from those just considered in two important respects. In the first place their densities increase toward their centers. For a given rate of rotation and mean density this central condensation makes them more nearly spherical, as is shown both by theory and by comparison of the observed figures of the planets with the computed forms of corresponding homogeneous masses. In the case of Saturn, for example, the eccentricity computed on the hypothesis of homogeneity is 0·607 while the observed value is only 0·409. It seems certain that this central condensation tends toward stability. The second important difference between the ideal homogeneous incompressible fluids and the celestial bodies is that the latter are compressible. This latter factor, at least under certain circumstances, tends toward instability.

"The opposing quantitative effects of central density and compressibility undoubtedly differ greatly in different masses and can not be easily determined in any case. However, if we may assume that they approximately offset each other, we may reach some conclusion respecting the possibility of the fission of the actual celestial bodies by discussing the corresponding homogeneous incompressible body. This is the assumption adopted here, but, because of its uncertainty, in the applications to the solar system, where it turns out fission is impossible, all approximations are made so as to favor fission, and it is assumed that in the actual bodies fission may be immanent long before it is possible in the homogeneous ones. These safeguards and simplifications are possible and easy because it is a negative result which is reached" (p. 158).

"For the applications we assume that an actual celestial body will not be in danger of fission until the corresponding homogeneous incompressible body arrives at the state where the Jacobian ellipsoids branch. The density at this stage is less than one-fourth that at which the pear-shaped figures branch, and actual fission in the homogeneous bodies is certainly beyond this form, if indeed fission into only two bodies is ever possible. With this very conservative assumption we proceed to some calculations.

"(1) We find that the sun can not arrive at this critical stage until its mean density shall have exceeded 307×10^{11} on the water standard. This corresponds to an equatorial diameter of the sun of about 22 miles.

"(2) We find that the sun can not become so oblate as Saturn is now until its mean density shall have exceeded 148×10^{10} on the water standard. This corresponds to an equatorial diameter of the sun of about 75 miles.

"Since even the latter density is impossibly great, we conclude that the sun will never become so oblate as Saturn is now, and that it will always be more stable than Saturn is now.

"(3) We find that Saturn can not arrive at the critical stage at which the Jacobian ellipsoids branch until its mean density shall have become 21 times that of water. This corresponds to a polar diameter of 16,500 miles and an equatorial diameter of 28,400 miles. We conclude because of the great density demanded that Saturn will never suffer fission.

"(4) We assume that the earth and moon were once one mass and get their original moment of momentum from its present value. In computing it, however, we make certain approximations so as to get it too large and thus favor the conclusion of fission, then we add to it the maximum amount the sun's tides can have taken from the earth, and finally we add 25 per cent for fear there may be some unknown sensible factors omitted. Then we find that this hypothetical earth-moon mass could not get even to the critical point where the Jacobian ellipsoids branch until its mean density became 215 times that of water, or about 40 times the present mean density of the earth and moon. It would not become even so oblate as Saturn is now until its density had become 10·4 times that of water. Therefore we conclude that the hypothetical case was false, and that the moon has not originated by fission from the earth in this way.

"(5) In applications to the binary stars the results are less definite because of the meager data regarding these systems. But assuming that fission in stars will occur when the Jacobian ellipsoids branch in the corresponding homogeneous masses, we find for the density σ in terms of water at the time of fission when the two stars are of equal mass

$$\sigma < \frac{0 \cdot 016}{P^2}$$

where P must be expressed in mean solar days. Even though fission should not occur until the density is ten times this amount (which, if true, makes the evidence against fission in the solar system much stronger), all visual binaries of two approximately equal masses must have separated, if they have originated by fission, while they were yet in a nebulous state. The results are of the same order so long as the disparity in the two masses of a binary is not very great, and this probably includes all of the visual binaries.

"(6) Certain formulas, not connected with the question of fission, were developed for binary systems" * * * *

"The results obtained by the computations given are quite adverse to the fission theory, in general, except if it is applied to masses in the nebulous state, and seem practically conclusive against it so far as the solar system is concerned, either in the future or past. Perhaps the hypothesis that stars are simply condensed nebulas, which has been stimulated by a century of belief in the Laplacian theory, should now be accepted with much greater reserve than formerly. Up to the present we have made it the basis not only for work in dynamical cosmogony but also in classifying the stars. It may be the time is ripe for a serious attempt to see if the opposite hypothesis of the disintegration of matter—because of enormous subatomic energies, which perhaps are released in the extremes of temperature and pressure existing in the interior of suns, and of its dispersion in space along coronal streamers or otherwise—can not be made to satisfy equally well all known phenomena. The existence of such a definitely formulated hypothesis would have a very salutary effect in the interpretation of the results of astronomical observations. We should then more readily reach what is probably a more nearly correct conclusion, viz., that both aggregation and dispersion of matter under certain conditions are important modes of evolution, and that possibly together they lead in some way to approximate cycles of an extent in time and space so far not contemplated" (pp. 159, 160).

In the next paper on "*The Bearing of Molecular Activity on Spontaneous Fission in Gaseous Spheroids*," T. C. Chamberlin considers from the standpoint of the moment of momentum the postulation of a shrinking gaseous spheroid reaching a critical stage at which centripetal and centrifugal forces balance each other in the equatorial zone. The problem to be solved is whether bodily separation of a portion of the spheroid would tend to take place, or whether it would shed material molecule by molecule. A discussion of the several outer zones of gas is given following the lines pursued by G. Johnston Stoney, and it is shown that molecules in the outer zone which reach the critical parabolic velocity will be directed forward owing to the velocity of rotation being added to the velocity of impact from behind. A certain per cent will further be given larger orbits owing to impact from below, and will thus become minute and independent satellites. In conclusion, Chamberlin states :

"Those molecules which make elliptical flights and return to the spheroid without collision carry back whatever moment of momentum they took out, but those thrown into permanent orbits retain, as a rule, not only what they took out but also the additional moment of momentum gained from the collisions which gave these free orbits. It follows that every molecule that goes into a free orbit takes a disproportionate amount of the moment of momentum of the spheroid and thus reduces its rotation, or else retards its increase of rotation, to that extent" * * *

"From the nature of the case, I entertain, with others, the view that the separation must take place molecule by molecule, and it seems to me inevitable that these molecules must go into orbits each carrying an excess of momentum at the expense of the spheroid, and hence that the critical stage of exact balance between the centrifugal and centripetal factors of the spheroid is never reached. If so, bodily separation is excluded by the conditions of the case.

"The conviction that such rotating gaseous spheroids must shed portions of their matter molecule by molecule, if they do so at all, has long been held by students of the subject, but I am not aware that the loss of moment of momentum from the spheroid has been urged as a reason why the critical state prerequisite to bodily separation may not be attainable" (p. 167).

The result of these last two papers goes to show on independent lines that celestial bodies cannot suffer bodily disruption owing to cooling and shrinking of their own mass attended by acceleration of rotation.

The following paper is on "*Geophysical Theory under the Planetesimal Hypothesis*," by Arthur C. Lunn :

"This paper is devoted mainly to a quantitative study of that portion of the earth's internal energy which is supposed to have been derived from the mechanical energy of a primitive system of planetesimals, of its transformation into thermal form during the epoch of accretion, and its subsequent redistribution by conduction" (p. 171).

It occupies sixty pages, and brings out important mathematical relations, but as it involves details regarding centrospheric conditions consequent upon one hypothesis of earth origin and is not so evidently a test of hypothesis, a detailed discussion may be omitted from the present review.

The final paper is on "*The Relations of Equilibrium between the Carbon Dioxide of the Atmosphere and the Calcium Sulphate, Calcium Carbonate, and Calcium Bicarbonate of Water Solutions in Contact with it*," by Julius Stieglitz. The purpose of the paper is to obtain a relation, if possible, between the chemical composition of gypsum deposits and the carbon dioxide of the atmosphere at the time of formation. The considerations developed make it desirable to examine such deposits of gypsum very carefully and exactly for even very small quantities of calcium carbonate. J. B.

2. *Second Appendix to the Sixth Edition of Dana's System of Mineralogy;* by EDWARD S. DANA and WILLIAM E. FORD. Pp. xi, 114. New York, 1909 (John Wiley & Sons).—Ten years have passed since the publication of the First Appendix to the Sixth Edition of Dana's Mineralogy, and during this time a very large amount has been added to the literature dealing with mineral species. This second appendix, now issued, gives a concise summary of this literature with full descriptions of all the well-established new species. Of these new species there are some sixty out of about two hundred new names, the remainder having been given to varieties and to imperfectly described minerals. The larger part of the labor on this appendix has been done by Professor Ford, who took up the work, when the senior editor was compelled to relinquish it, and carried it through to completion.

3. *Sketch of the Mineral Resources of India;* by T. H. HOLLAND, Director, Geological Survey of India. Pp. xi, 86, with two maps. Calcutta, 1908.—Many interesting points are brought out in this summary. It is noted that the total value of mineral production in India (for 1906) was £6,313,000; of this gold and coal made up two-thirds. Other prominent products in order of importance are: petroleum, manganese, salt, saltpeter and mica. The value of the ruby, sapphire and spinel mined was about £100,000 and of jadeite £64,400. India has now lost by foreign competition the prominent place she once held in her metallurgical industries, of iron, copper and brass, and chemical industries of borax, niter, alum, blue vitriol, copperas, etc. The rapid spread of railways, however, gives reason to hope that the increased local demand may restore something of the ancient prosperity in these lines.

4. *Igneous Rocks: Composition, Texture and Classification, Description and Occurrence;* by JOSEPH P. IDDINGS. In two volumes. Volume I. Pp. xi, 464, 3 plates. New York, 1909 (John Wiley & Sons).—This important work has recently been issued; a notice is deferred until a later number.

OBITUARY.

Professor SIMON NEWCOMB, the astronomer, died in Washington on July 11 in his seventy-fifth year. A notice is deferred until a later number.

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The past month has been a busy one and has brought us many consignments covering practically the whole world. They cover the finest grades of crystallized minerals, together with many rare and almost unattainable specimens and rich ores. Among these consignments were two old collections full of specimens from exhausted localities. These specimens must be seen to be appreciated.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXIII.—*The Physiography of the Central Andes: I. The Maritime Andes*; by Isaiah Bowman.

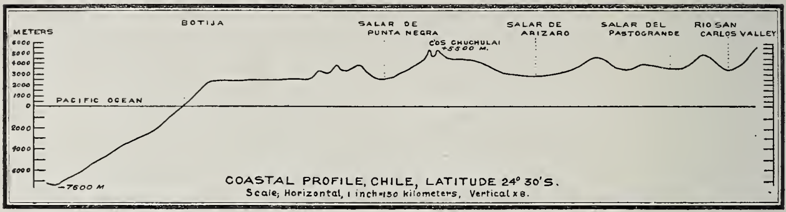
I. The Maritime Andes.

Coastal Features.

Among the long list of features which the western part of South America has in common with the western part of North America, none is perhaps more striking than the recent changes of level for which both are, from the human standpoint, unfortunately too well characterized. The recent destruction of Valparaiso occurred too soon after the San Francisco catastrophe for us to appreciate how appalling it actually was; while the lack of early newspaper reports from South America in years gone by no less than to-day has kept us from having even a reasonable appreciation of the frequency and destructiveness of the great earthquakes that virtually destroyed Arequipa in 1860, and Iquique, Arica, and Pisagua in 1877.

The entire western seaboard of South America supplies evidence of the magnitude of the crustal disturbances that the region has suffered in the past and is suffering to-day. The great height attributed to recent uplifts by Darwin has become a point of classic dispute, but whether his conclusions are accepted or rejected for the locality in question, there are elsewhere indubitable evidences of uplifts as great and important as those he concluded had occurred in Chile. The earth's crust is here unstable to a high degree, and constant changes, large and small, have aggregated an uplift among the most profound of those exhibited on the earth to-day. The cross-section, figure 1, represents the astonishingly abrupt transition from lofty tableland to abysmal ocean depth that is characteristic of the entire coast. It represents conditions along the coast of northern Chile in the vicinity of Taltal, where the Andes, attaining a height of over 16,000 feet, fall off to the enormous depth below sea level of over 25,000 feet, a total descent of over 40,000 feet in 175 miles. Of this descent, 32,600 feet is accomplished in 75 miles. From the northwestern coast of Peru southward to Concepcion, in southern Chile, the 4,000-meter submarine contour is never more than 125 miles from the coast and generally less than half that dis-

Fig. 1.



COASTAL PROFILE, CHILE, LATITUDE 24° 30′ S.
Scale; Horizontal, 1 inch=150 kilometers, Vertical x 8.

Fig. 2.

Fig. 2. Coastal Terrace at Payta, Peru.

tance away. We have here one of the great planes along which a major segment of the earth's crust is undergoing adjustment, the line of movement being oftentimes indicated by earthquakes and the amount by recently uplifted shore forms of unmistakable identity.

At the port of Payta in northwestern Peru one may obtain a very clear notion of the recency of the crustal movements that have affected the land thereabout. On the left of figure 2 a sea terrace only a few feet above sea level may be observed. It runs up each of the reëntrants and rounds all the spurs with even contour. Its materials are of exactly the same sort as those in the existing beach below it and the shells occurring in it are likewise identically like those of the present shore. It appears to have been formed but yesterday, so fresh are its details of structure and relief. Just outside the port, at the Punta de Foca, are wider terraces cut into the rock as well as the soft sands and gravels that overlie the rock. It is now being scored by the intermittent streams dependent on the seven-year rains, and is being cut off on the seaward side by wave action. Its smooth upper surface in the interstream areas is still strewn with wave-rolled material; and the beach, except for the work of the scoring streams, seems as in the previous case to have been exposed but yesterday.

Fig. 3.

Fig. 3. Coastal Terraces at Mollendo, Peru.

The most extraordinary development of wave-cut terraces observed were those at the port of Mollendo, in southern Peru, fig. 3. The terraces increase in height from the northern part of the Peruvian coast and reach a splendid development at this point. They are visible at sea as great, long, gently-sloping, rock benches of huge size. Opportunity was afforded for the more detailed examination of their upper surfaces than was possible in the preceding cases (Payta, Lomas, Pisco, Eten, etc.), and it was found that evidence for their formation by the sea and subsequent uplift to a height of at least 1,500 feet is conclusive. At an elevation of 800 feet, a clay bank was observed in the side of a gorge, or quebrada, in which in a natural position were found recent shells of the same sort as those now found in the present beach. It appears that, after the formation of the terrace at this level and its partial dissection as the result of elevation, it was again submerged long enough and deep enough for the formation of the clay and the deposition of the shells. A second uplift then brought the whole above water and it is this movement that is continuing to-day. About the inner margin of the terraces are coves like those now seen at many places on the present strand-line or but a little above it. They are not so clearly distinguishable as the latter because of the partial filling or obliteration that they have suffered, but their characteristic outlines are still to be made out with certainty. The whole aspect of the terraces with their regular outlines is in striking contrast to the highly irregular forms of the mountain side above them where the planing action of the sea is not expressed.

It would be a repetition of the foregoing descriptions to note the individual features of the different terraces observed along the coast farther south; and these have been described to some extent in the accompanying list of papers,* and their description here is unnecessary. At Iquique, at Tocopilla, Antofagasta, and elsewhere, they are developed as clearly as in the preceding cases. In each case the topographic outlines are as clear an index of their manner of formation as are the shells found upon the terraces at Payta and Mollendo. Though these shells are interesting confirmatory evidence, they are not really essential to the proof of formation by the sea and recent uplift, for the topographic evidence is of a thoroughly conclusive sort.

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* The literature of the subject is still very limited. The following are a few of the more important references:

a. Francisco Vidal Gormaz, Depressions and elevations of the southern archipelagoes of Chile (Scottish Geograph. Mag., Jan., 1902).

b. Von Otto Nordenskjold, Ueber einige Erzlagerstätten der Atacamawüste (11 B. Geol. 1. Univ. Upsala, iv, 1898).

c. D. H. Evans, Notes on the Raised Beaches of Taltal (Quart. Jour. Geol. Soc., xliii, 1907).

d. Charles Darwin, A Naturalist's Voyage, etc. Ed. of 1860.

Interior Features.

The evidences along the west coast of South America of recent tectonic adjustments are particularly clear because the uplifts which express these readjustments have occurred on the seashore, where a standard surface makes reasonably safe comparisons of relative land levels possible. They are particularly convincing by reason of the freshness of the uplifted shore forms, a fact owing to the recency of their occurrence at high levels and to the extreme aridity of the climate in which these forms occur, with their consequent freedom from the obliterating effects of rainwash, aided by chemical decay. This juxtaposition of recently made shore forms and competent agent of formation enables physiographic determinations to be made without hesitation.

It is a matter of great significance, from both the geological and the geographical viewpoint, to ascertain how generally this crustal deformation affected the interior portions of the central Andes. None of the geological arguments so far advanced by those who have examined the field has included any recognition of the clear evidences of crustal movements exhibited by topographic and drainage lines, and allied phenomena. In every case the arguments have rested upon purely paleontological or structural evidence. Furthermore, in the majority of cases, the analysis of drainage adjustments or directions is made with sole reference to and in close conformity with the presumptions raised by the strictly geological conclusions. Thus, for example, it is often argued that formerly the great interior sea of central Bolivia discharged into what is now the Amazon basin by way of the La Paz river, whose gorge through the Eastern Andes forms one of the profoundest clefts of that region. Now, whatever geological suggestions there may be for such an assumption, it is certain that the physiographic evidence (see Part II, The Eastern Andes) annuls the supposition in the clearest possible manner. Nor is this the only disadvantage which the present interpretations suffer. As geological history, the record of fluctuations of land level are of great importance even when such fluctuations are not marked by sedimentary deposits. They may condition, for example, the climate of the region and the character of the sediments which may ultimately exist; or they may form, as actually in the central Andes, the lost members in time of the series of recent geological occurrences. Their omission under the last-named circumstances means the omission of a part of the geological record in as important a sense as if glacial events and the forms which express them were omitted from the record. The fluctuations of level in the interior of the region are also easy to read, like those on the coast, but depend for their recognition upon a wholly different set of land-form relationships. These, and the considerations to which they give rise, will form the substance of the succeeding paragraphs.

Fig. 4.

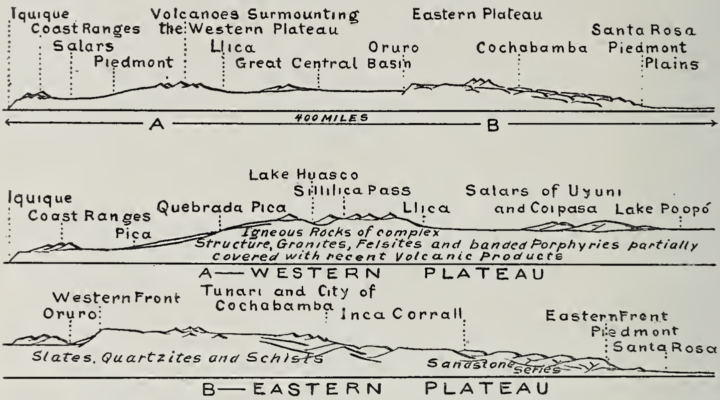

Fig. 4. Semi-diagrammatic topographic cross-section of typical conditions from Iquique, Chile, to Santa Rosa, Bolivia.

The dominating features of the central Andes (fig. 4) are two great plateaus with a central basin between them. The plateaus trend north and south and are depicted on the physical maps as two roughly-parallel mountain chains commonly referred to as the Eastern and Western Andes. In Bolivia, the eastern Andes are frequently and variously designated as the Cordillera Oriental, Eastern Cordillera, Cordillera of the East, or the Cordillera Real, the latter being an improper extension of the specific term applied to the lofty snow-capped mountain range near La Paz that is terminated on the south by El Illimani and on the north by Sorata. The Western Andes are usually called the Maritime Cordillera,* a generic term applied to the aggregations of individual peaks and short volcanic ranges which surmount the western plateau. In addition, specific terms are applied to the culminating ranges. Thus, on the boundary between Chile and Bolivia, latitude 20° south, there is the Cerro de Sillilica, just as in southern Peru the mountain knot at Vilcanote is called the Cerro de Vilcanote. Likewise in the eastern plateau the exceptional heights or the crests of the declivities that border basins and valleys are given specific names, as the Tunari de Cochabamba, the Cerro de Cliza, the Cordillera de Potosi, etc.

* C. R. Markham, Bolivia (Mills's International Geography, p. 840, 1901).

Between the two great Andine tablelands and their superimposed peaks and ranges is the central basin or plateau of lower altitude than the bordering highlands, separated from the latter by the two great roughly-parallel scarps of marked rectilinear quality often for long distances. This is the alti-plano or "planicie" of Bolivia. It is without outlet to the sea, an interior drainage basin, and therefore technically* a part of the true desert area of the world. On the north the bordering scarps converge in latitude 14° south, enclosing Lake Titicaca, whose waters discharge by way of the Desaguadero river into Lake Poopó, only to be discharged in turn into the Salar de Coipasa and the adjacent salars to the south. Here and there the otherwise flat basin floor is broken by piles of volcanic detritus, lava flows from occasional centers of igneous activity, as the Isla de Panza, of Poopó; or by ancient and highly crumpled sedimentaries, as where the upturned edges of slates and quartzites rib the hills back of the port of Desaguadero. East of the central Andes, as indeed along the whole eastern front of the Andine Cordillera, from the Argentine pampas to the llanos of Venezuela, the dissection of the adjacent highlands has been accompanied by the formation of extensive piedmont deposits. The western plateau descends by a relatively smooth slope to the coastal deserts of Tarapacá and Atacama. Between these deserts and the Pacific shore are low mountain ranges of complex geologic and physiographic character, the coast ranges of Chili and Peru.

With this general statement of the lie of the land and its principal topographic outlines, we shall next consider current explanations and then the more technical aspects of the physiography, the genesis and development through time, of the principal topographic and drainage features.

All of the older and most of the newer descriptive text-books of geography describe the western Andes as a majestic line of lofty volcanoes with deep abysses and precipitous walls and canyons, a stupendous volcanic pile rising sheer from the sea. This conception was natural to the text-book writer reading the traveler's account of lofty Chimborazo, whose white summit (21,000 ft.) is visible on clear days from the gulf of Guayaquil; or of El Misti, with 11,000 ft. of relative altitude, at Arequipa, Peru. True it is that in the south, where the Patagonian Andes terminate this great orographic system, there is a mountain-bordered shore which for scenic grandeur meets the expectations of the liveliest imagination. But the peaks are here not volcanic cones and the absolute altitudes fall far short of those

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* Dr. John Murray, Origin and Character of the Sahara, Science, vol. xvi, p. 106, 1890.

in other parts of the system. It is a common experience to find these conceptions of the early books generally held to-day.

Two specific examples from reasonably authoritative sources will be accepted as the standard conceptions current among students of the subject. These will form points of departure for the new considerations which follow. The first deals with both the eastern and western "mountain" (plateau) systems, the second with the western only. The one is a compilation by Herbertson from various original sources, and is taken from Mills's International Geography, a superior and strictly modern reference work; the other from Sievers, the best general German work on South America. Herbertson describes the Central Andes as follows:

"From 40° S. to 4° S. the Western and Eastern regions of the Cordillera differ both in composition and age. The Eastern ranges were folded earlier than the Western ranges, where the folds are more marked. A series of young volcanic rocks comes between the Eastern and Western regions; and along a line which clings to the Eastern foot of the Western or main range, there are numerous active volcanoes. The Western range remains uniform in structure thoughout its vast length" (p. 817).

The second reference is to Sievers' Süd und Mittel-Amerika, published in 1903. "Diese Vulcane sind der Westcordillera aufgesetzt, erheben sich über das 4000 bis 4500 m höhe Grundgebirge zu höhen von mehr als 6000 m und geben dem Gebirge seine characteristische Erscheinung" (p. 390). It cannot be denied that from the purely scenic standpoint the volcanoes are the principal features of the western Cordillera, but from the morphologic standpoint they are of far lesser importance than the platform (the "Grundgebirge" of Sievers) upon which they rest.

The best corrective to the notion that the central portion of the Maritime Andes owe their height chiefly or even largely to volcanic accumulation, or that they consist in the main of a series of meridional ranges, is to be found in the appearance they present from any point on the Lagunas nitrate railway back of Iquique, Chile, from Pintados southward. It is hard to conceal one's astonishment on first catching sight of the great highland which there lies on the eastern horizon, presenting as it does for at least forty miles in a north-south direction an unbroken summit so nearly absolutely level as to give an appearance of pronounced artificiality. It is this fact, supported by a score of similar ones from widely separated points, that supplies the organizing principle in the physiography of this whole region. It will be shown that we have here an uplifted peneplain, whose position 14,000 ft. above sea level, constitutes it one of the most interesting and important physiographic units to be found anywhere upon the earth, particularly as large portions of it, by virtue of the pronounced aridity of the climate even at these high elevations, have remained in a relatively undissected and therefore safely determinable condition up to the present time.

Every step of the traveler's approach to this great uplift increases his astonishment at the perfection of the but slightly modified peneplain remnant there disclosed. The view represented in fig. 5 gives one but an inadequate notion of the perfection it displays.

FIG 5.

FIG. 5. The "crest" and western slope of the Maritime Andes (plateau) as seen from east of Pica, Chile.

On the left (north) are the unexplored Altos de Sitilca, presumably volcanic, and on the right (40 miles farther south) are the gentle outlines of the Chacarilla mountains. Between these two volcanic piles is the unbroken level of the plateau. The winding precipitous gorges (quebradas) nick its edge deeply, but at a distance even this mark of dissection is unobservable and only the impressively level sky-line stands out sharp and distinct. A straight-edge projected under the line does not enable the eye to discover a single important departure from horizontality in the whole forty-mile section.

The same regularity marks the descent of the western edge of the plateau beneath piedmont deposits. The average of many observations gives 7° as the mean value of this descent while the mean descent of the overlapping piedmont surface lies somewhere between 3° and 5°. This relation is expressed in fig. 6.

One of the best localities for the study of the peneplain surface whose warped slope descends beneath the piedmont is found a long half-day's journey east of Pica, or about 70 miles east of Iquique and a short distance north of the trail to Lake Huasco. The altitude is 5,800 ft.* (A. T.) There, in the bottom of the Quisma gorge is a pronounced unconformity showing sandstones, conglomerates, and more recent alluvium,

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* Aneroid determinations are to be understood in every case unless it is specifically indicated otherwise.

of variable degrees of induration, lying upon light-colored felsite. The unconformity is singularly regular and shows on the one hand a smooth surface gradually descending beneath the piedmont, while on the other it ascends with equally regular slope to the summit of the plateau fifteen to twenty miles to the east. The line of unconformity as it appears at 10,100 ft. is represented in fig. 6, where the upper lighter piedmont deposit is shown resting upon the felsite. The ascent of the slope leading to the summit of the plateau discloses a surface thinly veneered with slabs and flat stones of great dimensional heterogeneity. This fragmental material is clearly the result of the extremes of night and day temperatures, for, in the practical absence of vegetation and at these altitudes 8,500 to 15,000 ft. above the sea, solar radiation, especially during summer, heats the rock to an incredibly high temperature, while at night the rare atmosphere favors equally pronounced terrestrial radiation under an unclouded sky. The consequence is a continual rock peeling, a process only obscured when the action has continued to the point when a protective

Fig. 6.

Fig. 6. Erosion surface between piedmont and underlying igneous rocks east of Pica, Chile. The surface may be distinguished by differences of shade in right background.

cover has been formed in spite of the continual removal of the smaller products by winds and a small amount of rainwash. Fine material, in general present in great quantities when rock is chemically decayed, is here practically absent and but partially fills the interstices among the slabs and blocks. It is a cluttered slope, minutely rough, but in its distant aspect it is of gentle declivity and great smoothness.

Somewhat regularly spaced along the western descent are the steep-walled gorges of the westward flowing streams. Their descent is gentler than the 7° slope of the plateau margin; and in many cases they have cut profound canyons toward their headwaters. The Quebrada Quisma of fig. 6 is several hundred feet deep where the trail ascends its walls at 13,000 to 14,000 ft. elevation, east of Pica. The Chacarilla gorge, farther south, is nearly a half mile deep between the Victoria mines and the oasis of Chaia. The stream profiles, in spite of the adjustments represented by these enormous clefts, are still abnormal and show a steepening of the lower sections over the upper below the point where they pass the edge of the plateau, thus clearly reflecting the effects of recent elevation.

From 12,500 ft. to 13,000 ft. the edge of the plateau is occasionally marked by rock ledges 20 to 40 ft. high.

Fig. 7.

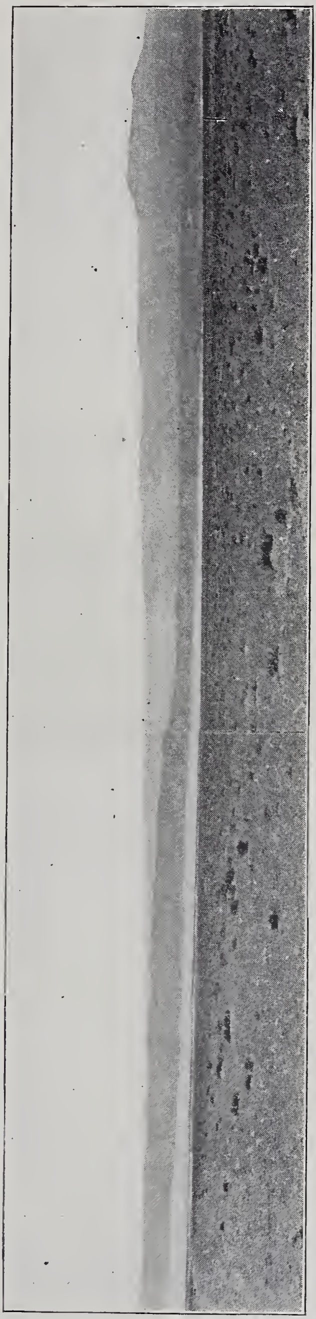


Fig. 7. Undissected peneplain remnant on the western border of Lake Huasco. Fault scarp in left background. Twenty-five miles of country in view.

Their crumbling scarps are the last ascent one makes in reaching the upper level of the plateau. From this altitude to the highest altitude one attains on the peneplain remnants of this vicinity (15,000 ft.) the slopes are relatively gentler. Nowhere does one gain a more impressive notion of the extent and character of these undissected surfaces as from the 12,500 ft. level east of the spring at Laguno Huasco, fig. 8. The photograph (fig. 7) scarcely needs an interpretive text. In it one looks a little north of west and observes from foreground to background about 25 miles of country, and perhaps an equal distance from left to right. The plateau surface frequently referred to above is on the sky-line. The camera stands upon a great alluvial fan tributary to the basin of Lake Huasco; and the basin itself is limited on the west by the bold and ragged thousand-foot scarp that descends toward the observer in the middle distance. The degree of baseleveling attained in this region is brought out strikingly in this view as well as in fig. 6, where, however, it occupies a warped attitude, assumed since peneplanation.

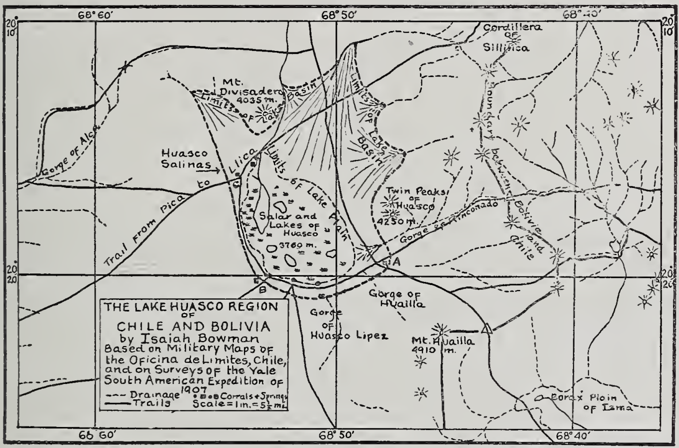
It would be singular indeed if the great altitude of the old surface thus described had been acquired in a single period of crustal deformation. The history of other regions raises the expectation that successive uplifts, rather than a single profound uplift, would occur, separated by periods of relative quiet during which the drainage lines and the topography would become organized with respect to the new base level. This expectation is more definitely and abundantly met in the eastern plateau than in the western, by reason of climatic influences to be defined later, but even in the western plateau we have specific cases pointing to this conclusion.

The fact of successive uplifts may perhaps be presented more clearly after some consideration of the present attitude of the deformed peneplain where block faulting has occurred. In fig. 6 the gently warped, western slope of the plateau is represented as a practically smooth descent with but minor dislocations. These dislocations have a considerable interpretive value, as will appear in the further discussion, but they do not destroy the general regularity of the flanking slope. In fig. 7 it has already been noted that while a portion of the peneplain occupies a nearly flat position, its continuity is broken in the middle distance by a thousand-foot slope and scarp, the western border of the basin of Lake Huasco.

The basin quadrant which lies to the southeast of Lake Huasco, fig. 8, is a huge fault block which gained its present attitude after peneplanation. The scarp which limits the basin on the west is the locus of the fault, and the basin itself is the product of a dislocation whereby the western edge of the block retained its initial altitude after uplift while the eastern portion was depressed; the basin thus formed receives a limited rainfall, and even in the wetter climate once prevailing had no outlet to the sea.

The fact that this blocked quadrant was formerly baseleveled appears from the relation between surface and structure that obtains in the gorge of Rinconado, which enters the basin immediately south of the twin peaks of Huasco. The gorge is 200 ft. in depth, with nearly vertical sides, and reveals a clearly featured section. The granite-gneiss forming the body of the block has many structural deformities, a fact which is variously expressed, in some places by faults impossible of restoration on account of the homogeneity of the mass; in other places by anticlinal structures. The present surface of the block is exceedingly regular and smooth except where locally roughened by stream dissection; and is remarkable for the exact regularity with which it cuts across the irregularities of structure. This truncated condition coupled with the extraordinary evenness of the blocks in their general aspect forms one of the most constant and striking features of the region. The block now slopes northwest, occupying a tilted position with respect to its plane of origin.

Fig. 8. *



The fault scarp of the western edge of the basin, the locus of movement for the tabled block constituting the southeastern quadrant of the basin, has been but slightly modified by stream erosion since faulting. It possesses two important genetic qualities which reveal its true nature. First of all, the material composing the block thus scarped is essentially identical in

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* Refer to parallels for correction of scale.

lithologic character with the downfaulted block forming the southeastern quadrant just described. It possesses no textural peculiarities which might account for the formation of the great thousand-foot declivity of remarkable simplicity, straightness, and definiteness of trend. If further evidence were needed that the succession of events were the formation of structural irregularities, peneplanation, and block faulting, it is to be found on the face of the scarp here considered, where the flat upper surfaces of the block, a peneplain remnant of unmistakable identity, is suddenly terminated by this great rectilinear wall. Furthermore, not only the succession of the major events which those conditions signify, but also the fact of faulting is established by the manner in which this rectilinear scarp trends regardless of structure. While time did not permit the detailed examination of the structural geology, it was forcibly impressed by the evidence of several critical localities that we have here that inharmonious relation of mountain form and mountain front to structural axes so significant of long intervals of topographic development between periods of crustal deformation.

It is the lack of correspondence between the trend of the scarp and that of the structural axes that at once dismisses the initial structure as the cause of the scarp and establishes the fact that the scarp was formed in a second structural epoch. That this second epoch is of much more recent date and quite unassociated with the first in time, as the above consideration shows it to be different in kind, is established by the length of time required for the old flat surface to attain the perfection here displayed and the well-nigh complete discordance it exhibits with respect to the initial structure. The peneplain thus bevels the first set of structures and is itself cut into large well-defined remnants, or blocks, by the second and much later set of structures—the fault planes which are the loci of recent block displacements.

At the time of major displacement the Huasco basin must have been lowest in its northwestern extension, this being the direction in which the southeastern block quadrant was tilted. At present the salt lake of Huasco occupies a position south of the center of the basin, having been displaced from its earlier more northerly position by the filling of waste material in the form of enormous alluvial fans heading in the valleys among the lofty volcanoes which occur in this direction. These great volcanoes (fig. 8) are a portion of the Sillilica range, the most important members being V. Sillilica, the twin peaks of Huasco, Sacaba, and Mt. Divisadero.

The volcanoes rest upon the broken and tilted fragments of the peneplain which is clearly discernible about the borders of their flows but which becomes indistinguishable beneath the mass of volcanic detritus in the heart of the range. An important feature of the outlying volcanoes such as the volcano Pelaya, on the southern border of the Borateras de Isma, is the apparently complete adjustment of their lava flows to the present attitude of the tilted blocks which they surmount. It is especially noteworthy here by virtue of the strong tilt imposed upon the block that is the impediment; and indicates, for this case at least, the fact that some of the volcanic flows were later episodes than the block faulting. The volcano in point is on the western side of the borax plain called the Salar de Empesa (see general map of Bolivia). One of the flows from its crater forms the steep wall on the south side of the bay, the Boratero de Isma, that juts toward the west from the main depression. The principal basin itself is but the down-faulted block whose nature is sufficiently well indicated by the 800-foot fault scarp that forms its southeastern margin and visible from the west side of the lake as a steep and nearly straight wall, cutting across a thick series of earlier and now deformed mass of igneous rocks.

These descriptions of the present condition of the once lower and flatter peneplain, and the proof of its existence, enables the brief presentation of a few facts which seem to indicate two periods of uplift separated by alternate intervals of quiet. The first is the occurrence of terraces just within the edge of the plateau. These are well-defined and are clearly not of structural origin, the rock in this locality, Quebrada Quisma, being massive crystalline. The descent of the upper valley slope from the topmost level of the plateau is relatively gentle and the top of the terrace descends with still gentler grade to the exceedingly steep descent of the gorge-like inner valley. The terrace is conspicuous virtually to the head of the valley—ten miles eastward—and continues down stream to within a half mile of the edge of the plateau. Here it disappears, the flat upper slope being displaced by a continuous and steep descent to the valley bottom. Such a terrace originates the conception of two uplifts. The first was followed by valley development to the point of well-graded valley slopes, although the dissection of the flat plateau surface had only been begun on account of the aridity which characterizes the region. The second uplift is marked by that deep dissection which the now incised stream has accomplished. The inner valley is a narrow gorge with persistently steep and in places vertical sides, a contrasting condition with respect to the outer valley, which suggests that the time that has elapsed since the last uplift is short compared with the interval between the two uplifts.

Confirmatory evidence of general uplift with respect to which the present drainage has not yet been adjusted is found in the abnormal profile of the thalweg of Quebrada Quisma an eighth of a mile eastward of the edge of the plateau. From a relatively flat upper portion a change is made to a steeper gradient virtually on the edge of the plateau.* This condition was accurately determined by field measurements.

A second feature interpreted as a probable indication of two periods of displacement of the blocked sections of the peneplain, is worthy of note here. It suggests that these displacements were accompaniments of the general uplift that the region experienced and therefore but the different expression of a cause common to the two adjustments. It is the appearance of the edge of the block illustrated by fig. 7. The upper part of the scarp descends by a somewhat smooth and relatively gentle slope to a shoulder of more or less definition where the descent is continued with distinctly increased steepness to the foot of the scarp. The effect on the drainage lines is to give them all reverse curve profiles but slightly readjusted to the present outline of the edge of the block. This appearance is very striking as one views the block of fig. 7 from the lower slopes of the twin peaks of Huasco. It also comes out with great distinctness as one descends the trail from the southwest to the spring at the western edge of the basin and passes in review the various features indicated.

It is concluded that this relation of upper and lower slopes signifies two periods of faulting separated by a pronounced interval of stability in the relative positions of the affected blocks. The upper slopes would, if this view be correct, represent the graded condition which was reached after the first period of faulting, while the renewal of the fault would again define the face of the block by recreating the fault scarp.

In a desert region of active faulting the opportunities for the occurrence of antecedent drainage are obviously diminished as compared with the possibilities of a humid region. It therefore did not seem probable when the field was first examined that any clear cases would be discovered where the present attitude of the block would be disregarded by a transverse stream. Indeed, all of the first streams examined about the Lake Huasco district showed strong conformity with the dominating slopes. It was, therefore, very gratifying to find, in the last inspection of the field on the return journey

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* An interesting topographic complexity is exhibited in the last three-quarters of a mile within the margin of the plateau. It consists of a second terrace distinctly below the level of the first and of decidedly limited development. The origin of this second terrace is, however, not of immediate interest here and will be described in a later paper.

across the Maritime Andes, a clear case of such antecedency. The occurrence is just south of the volcano Hoailla, a full half day's ride southeast of Lake Huasco. From a low, flat divide, a fourth of a mile or more across, a valley begins whose descent is west toward Lake Huasco, to which it is tributary. The valley is at first flat-bottomed with tiny meander scallops on the margin of the valley flat. It continues with this character a half mile or more, then deepens and narrows gradually, and is finally transformed into a gorge a half mile long that transects the edge of the block.

This feature has significance in the analysis of the landscape hereabout, in that it clearly establishes the fact of deformation after the establishment of definite drainage lines upon a flatter surface. The persistence of the downcutting stream, across the uplift, has resulted in the curious aspect of a stream flowing westward in a direction precisely opposite to that suggested by the general eastward slope of the block to-day.

The conditions described in the preceding paragraphs occur chiefly in the Lake Huasco region. We shall now turn to a more southerly district, that of the Chacarilla mountains, for topographic and structural features of the greatest importance in the interpretation of the western Andes.

FIG. 9.

FIG. 9.—Fifteen-mile semi-diagrammatic section of the Chacarilla gorge on the western slope of the Maritime Andes, east of Allianza, Chile.

Were clear evidence lacking in other localities of a protracted period of erosion during which the land surface, now a part of the western Andes, was reduced to a plain of slight relief, it would suffice to rest the proof upon the evidence afforded in the walls of the Chacarilla gorge. Here is displayed for fully fifteen miles, namely, from above the oasis of Chacarilla to Algarrobal, an unconformity of exceptional definition. Fig. 9, which displays it diagrammatically, scarcely needs interpretation. Below the unconformity is a banded rock of diverse structure, only suggested by the details of the figure. These structural irregularities are planed off with great regularity, and are overlaid by a thick series of flat sandstones and conglomerates. The unconformity is easily located in the field, not only by the structural contrasts suggested in the sketch but as well by the contrasted topographic architecture in the gorge wall above and below the contact. The sandstones and conglomerates weather with typical Grand Canyon effects,—an alternating series of vertical scarps and sloping taluses characterizing the upper part of the section, while the lower part is irregularly dissected, presenting every complexity of slope arrangement. Above Chacarilla the piedmont deposit thins out and disappears towards the edge of the plateau.

The distance from the crestline of the Andes (east of the Chacarilla mountains) to the seacoast is approximately 80 miles. At Cerro Gordo a distinct block rises above the piedmont slope, breaking its continuity for several miles, and again directly west of the Pique pumping station, a granite block juts sharply above (500 ft.) the general level. In the well-nigh absolutely arid climate of the region the but partially rounded edges of these blocks reflect their original outlines with remarkable distinctness. The upper surface of the Pique block (3,500 ft.) is flat to gently rolling, only rounded knobs of slight extent surmounting the generally even surface. The peneplained character of the block appears from the general evenness of its surface as developed on rocks of diverse structure and hardness. The western part of the block is composed of sandstones, the eastern of a fine-grained resistant igneous rock, both reduced to a common level. Toward the eastern margin the surface becomes slightly dissected, long fans of waste choking the mouths of ravines and stretching out over the saline crust that forms the salars, the stark desert places of the province of Tarapacá. Such dissection is, however, decidedly inconsequent on the whole; the ineffective drainage results, even on the ravine sides, in a waste cover so deep that only here and there are rock outcrops distinguishable. The edge of the block is, therefore, clearly limned as a strikingly even and abrupt escarpment, but imperfectly dissected by the feeble, intermittent streams.

The view from the Allianza nitrate station of that part of the now warped and uplifted peneplain which includes the Chacarilla mountains is represented in the rough sketch in fig. 10. The summit of the upwarped plateau retains the general character here depicted, southward beyond Santa Fé in the Loa Valley (see general map of Chile). At Calama the old initial surface was again observed as a tilted block south of the oasis of that name, where it stands out with unfailing clearness. This baseleveled surface, with whose identification, broad aspects, and detailed character at critical localities we have thus far been concerned, has thus been observed to occur for over one hundred miles, from Calama to Tarapacá. It will be of interest to note how generally it occurs in other parts of the central Andes.

While opportunity was not afforded to study in the same detail the interesting plateau section east of Arica, Chile, the photographs of the plateau, fig. 11, made from the summit of the 1000 ft. hill northeast of the port of Arica, will suggest with what probability the peneplain is known to occur in this locality. The views include about 50 miles of country. The 14,000 ft. (?) tableland constituting the summit of the Cordillera (beyond the left of the photographs) is so flat that this quality, and not the lofty snow-capped peaks surmounting the tableland, forms, physiographically considered, the most conspicuous feature of the landscape. With what structural quality the descent is made to the intermediate level in the photographs, and what the genetic relation of these two tablelands is, was not determined. From the detailed geomorphic study made directly south, of similar relations, it is not an unreasonable assumption that the two surfaces were once continuous and that the zone of displacement is represented by the descent from the upper platform.

Fig. 10.

Fig. 10.—Detailed view of southern end of sketch, fig. 5, looking east from Allianza, Chile.

The lower wind-swept platform of this vicinity presents a hard-featured landscape of remarkable flatness, now deeply covered with drifting sand, now roughly cloaked with angular fragments, from which the fine material has been sifted by the constant wind. It is wonderfully impressive to one who comes prepared to see a line of precipitous volcanic heights to find these great flat-topped tablelands dominating the view, only partially relieved toward evening by the fine appearance of the distant snow-capped peaks.

Again at Crucero Alto (14,000 ft.), Peru, on the railway from Puno to Mollendo, one rises well towards the level of the great plateau and sees extending out in every direction the topography suggested by fig. 12. For physiographic purposes it would be useless to describe the structure in any detail, so universally complicated is it. But in spite of the enormous plications and irregularities everywhere observable the upper

Fig. 11.

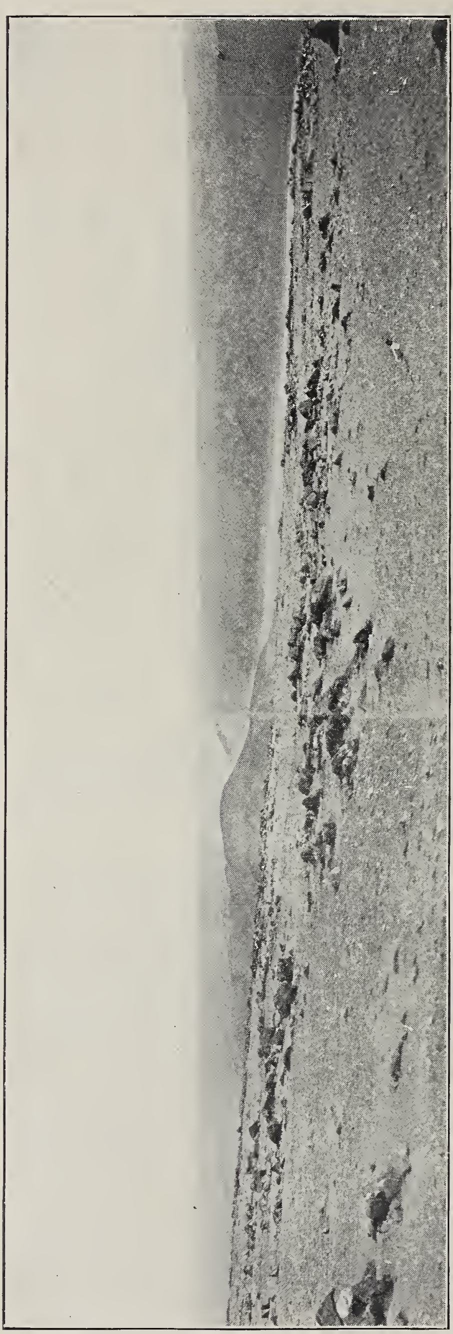

Fig. 11. Baseleveled surface east of Arica, Chile.

surface of the plateau remains strikingly true to this level. West of these localities and toward the coast the initial features are complicated and rendered indistinguishable by great warps and faults and by the masses of volcanic debris that appear east of Arequipa.

Fig. 12.

Fig. 12. General view of the baseleveled and now uplifted and dissected Maritime Andes, near Crucero Alto, Peru. Altitude about 14,300 feet.

A study of the map will show the great extent of territory involved in the explanation here suggested and will clear the way for the study of the eastern plateau, whose physiography will be found to have a similar interpretation. In the following chapter will also be discussed certain features of the physiography and geology of the Maritime Andes, which are best treated in connection with similar features in the eastern Andes with which they are genetically related.

(End of Part I.)

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Art. XXIV.—*Geology and Structure of the Ancient Volcanic Rocks of Davidson County, North Carolina;*[*] by J. E. Pogue, Jr.

Introductory.

Preliminary statement.—The present article outlines the more important, non-economic portions of a geological report, presented as a thesis at Yale University in June, 1909, and prepared under the direction of the North Carolina Geological and Economic Survey. It is based upon three months' field work done in the summer of 1908, and upon laboratory and office work carried on during the autumn, winter, and spring of 1908–09 in the Petrological Laboratory of the Sheffield Scientific School of Yale University.

Location and geography.—The area described is known as the Cid Mining District and is situated in the central portion of North Carolina, within the Piedmont Plateau, and near the western boundary of a great series of volcano-sedimentary rocks, the Carolina slate belt, which crosses the state in a northeast and southwest direction. The tract covers approximately 125 square miles, and was mapped in detail on the scale 1 : 24,000. The average elevation above sea level is about 600 feet, and the range of elevations within the district is about 300 feet. This range may be encompassed by long, almost imperceptible slopes, not disturbing the appearance of subdued relief; or by sudden rises, with rugged topography as a result. The district accordingly presents not only features common to gently rolling, maturely dissected regions, but also in places has a surface configuration comparable to mountainous topography on a small scale. The drainage is into the Yadkin River, which forms the southwestern boundary of the area and flows across the structure, cutting alike through hard and soft formations. The minor streams, parallel to one another and at right angles to the Yadkin, are in conformity with the structure and have thrown into relief northeast trending ridges, locally called "mountains." The most conspicuous of these is Flat Swamp Mountain, which forms a part of Flat Swamp Ridge extending as a narrow ridge for nearly 7 miles through the central portion of the district. The region is sparsely inhabited and contains only a few small villages. It has been of some importance as a mining center and contains the Silver Hill, Conrad Hill, Silver Valley, Emmons, Peters, and other mines—of which the Silver Hill is the best known.

Historical sketch.—It was not until 1894 that the presence of rocks of volcanic origin within the Piedmont Plateau of

[*] Published by permission of the State Geologist of North Carolina.

North Carolina was recognized. In that year, George H. Williams,* in a paper on the distribution of ancient volcanic rocks along the eastern border of North America, announced their identification in Chatham County and near Chapel Hill, and suggested their probable wider distribution. Since then, Becker,† Nitze and Hanna,‡ Weed and Watson,§ and Graton‖ have described in a general way; and Laney,¶ and after him the writer, have considered in detail areas of these rocks and established their wide occurrence.

General Geology.

Outline.—The portion of the Piedmont Plateau herein described exposes the beveled folds of a great volcano-sedimentary formation. A traverse across the district from northwest to southeast passes over the eroded edges of once horizontal beds, which show upon the surface as elongated belts and lenses. Their character indicates an origin during a period of great volcanic activity.

Wide bands of a sedimentary, slate-like rock, composed of varying admixtures of volcanic ash and land waste, have the greatest areal extent. Intercalated with these occur strips and lenses of acid and basic volcanic rocks, represented by fine and coarse-grained volcanic ejectamenta and old lava flows. The acid rocks include fine tuffs, coarse tuffs, and breccias, chiefly of a rhyolitic and dacitic character, together with flows of rhyolite and dacite. The basic series embrace fine tuffs, coarse tuffs, and breccias of an andesitic nature, and flows of an andesitic and trachy-andesitic stamp. Gabbro and diabase dikes cut the other formations.

The region has suffered a period of severe dynamic metamorphism, consequent upon a great compressive force which squeezed the beds into enormous folds; followed by a time of chemical alteration and mineralization; which in turn was succeeded by a long period of erosion and weathering. The rocks have suffered to a variable degree from all these factors.

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* Williams, George H., Distribution of Ancient Volcanic Rocks along the Eastern Border of North America. Jour. Geol., v. ii, 1–31, 1894.

† Becker, G. F., Gold Fields of the Southern Appalachians. (In U. S. Geol. Survey, 16th Ann. Rept., pt. 3, 1895.)

‡ Nitze, H. B. C., and Hanna, G. B., Gold Deposits of North Carolina. N. C. Geol. Survey, Bull. 3, 1896.

§ Weed, W. H., and Watson, T. L., The Virginia Copper Deposits. Ec. Geol., v. i, pp. 309–330, 1906.

‖ Graton, L. C., Reconnaissance of some Gold and Tin Deposits of the Southern Appalachians. U. S. Geol. Survey, Bull. 293, 1906.

¶ Laney, F. B., The Gold Hill Mining District of North Carolina. A Thesis, Yale University, 1908.

Laney, F. B., and Pogue, J. E., Jr., An Outcrop Map of the Virgilina Copper District of North Carolina. Scale 1 : 24,000. N. C. Geol. Survey, 1908.

Fig. 1.

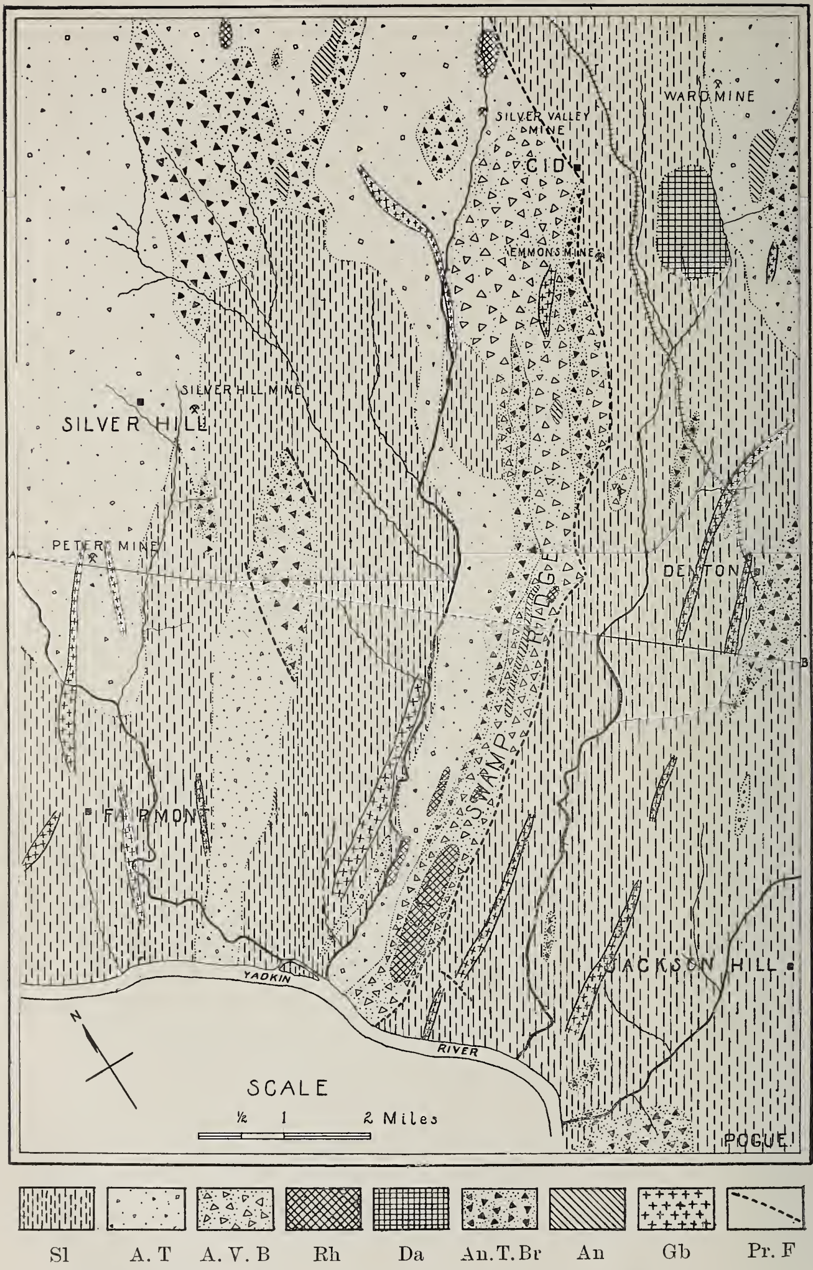

Fig. 1. Geologic Map of the Cid Mining District, Davidson County, North Carolina.

Explanation of contractions: Sl, slate; A. T, acid tuff; A. V. B, acid volcanic breccia; Rh, rhyolite; Da, dacite; An. T. Br, andesitic tuff and breccia; An, andesite; Gb, gabbro; Pr. F, probable faults.

In general, each formation has a massive and a mashed or schistose phase, with every gradation between the two. The passage of heated solutions affected all formations, as evidenced by the mineralized zones, the abundance of quartz veins, and the high degree of silicification in many belts of rock, and the universal occurrence of infiltrated iron ores. Finally, erosion has planed off all the upper portion of the folded series; but weathering has proceeded in excess of erosion to such an extent that the region is now deeply decayed, so that only here and there do the rocks project through a thick mantle of decomposed rock or soil.

This threefold set of changes undergone, each cumulative in its effect, has given rise to an almost infinite number of rock variations; but a consideration of the rocks which have suffered the least dynamic and chemical change renders it possible to establish a definite number of distinct, though related, rock types, to which the more altered derivatives may be referred.

Slate.—The rock here designated as "slate" is not a normal product of land erosion, but bears evidence of a peculiar origin by a liberal admixture of fine-grained volcanic ejectamenta. It occurs in broad bands, with a northeast trend, separated from each other by belts of volcanic rocks. It shows upon the surface as low, elongated, parallel reefs or ledges. These are never very abundant nor continuous, because the rock easily weathers to a soil. Associated with the slate are rather frequent outcrops of the acid and basic tuffs; the slate in many places grades imperceptibly into the acid fine tuff.

When fresh the slate is a dark green, dark to light blue, or grayish black to black rock. With increasing proportions of ash, these colors grade into lighter shades, and finally into light grays and whites. Upon weathering, the colors brighten and become quite diverse and sometimes even brilliant. Shades of purple, blue, green, red, yellow, and gray, in endless variations, may appear. In texture, the rock is so dense that little can be discerned with the unaided eye. In many occurrences bedding planes are visible, bespeaking the sedimentary origin of the rock. Much of the slate is massive, but in many portions of the district it has been mashed to a greater or less extent, so that it splits easily along certain directions. Some of the mashed phases also show bedding planes; these only in part agree with the schistosity. The rather anomalous term "schistose slate" seems appropriate for some phases of the rock.

The most interesting and significant feature in regard to the slate is the relation between its soda and potash content. Several analyses show that the ratio of Na_2O to K_2O varies from 1 : 1 to 6 : 1. This excess of soda in a sedimentary rock is very unusual. For comparison, an average was made of the percentages of alkalies found in the 33 slates analyzed in the chemical laboratory of the United States Geological Survey from 1880 to 1903,* with this result:

Average $Na_2O = 0{\cdot}89$ per cent.
" $K_2O = 3{\cdot}68$ "

The ratio of soda to potash is 1 : 4·1. Only two of the 33 slates fail to have at least twice as much potash as soda; and in no instance is the soda in excess. These figures show that the material of a normal slate, during an ordinary cycle of land erosion, loses soda much more readily than potash; so that the final result is a preponderance of potash over soda, irrespective of the original proportions. When the reverse is found to be the case, special conditions must be sought to explain this unnatural relation.

In the slates of the Carolina slate belt, the soda is equal to or in greater amounts than the potash. According to the quantitative nomenclature, the Carolina slate is sodipotassic to dosodic; whereas, a normal slate is dopotassic. This feature indicates that the rock has not undergone a normal cycle of erosion; for such would have brought it in line with the average slate. On the contrary, it suggests that the original material of the rock was transported only a short distance, and, further, that the material was presented to the transporting agent in a condition of mechanical disintegration. A long transport of finely comminuted material would have resulted in the deposition of sediments low in soda. A long period of chemical weathering, previous to transportation, would have had the same effect. The conclusion, which is strengthened by the geologic occurrence, microscopic make-up, and gradation into tuff deposits, is that the slates were derived chiefly from great masses of volcanic ejectamenta, and deposited by water, with varying amounts of land waste, at no great distance from the source of the material.

The acid series of volcanic rocks. Acid fine tuff.—The acid fine tuff occurs interbedded with the slate and the acid coarse tuff, and is transitional into each. It has no wide-spread areal extent, but is abundantly distributed in very narrow lenses, often represented by single outcrops. These are often intimately associated with outcrops of the acid coarse tuff, and the two form tuff bands parallel to the belts of slate. At times there are frequent alternations in the course of a few yards between fine tuff, coarse tuff, and slate, bespeaking a rapid change of conditions during deposition.

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*Clarke, F. W., Analyses of Rocks. U. S. Geol. Survey, Bull. 228, pp. 337–346, 1904.

The rock varies considerably in appearance from place to place, depending upon its degree of silicification and schistosity. Much of the massive tuff is highly siliceous, varies in color from cream through gray to black, and breaks with a conchoidal fracture into chips with keen, translucent edges. The outcrops are badly jointed and emit a metallic sound when struck with steel. This type resembles flint or chert and is locally called "gunflint." Another phase of the rock is less dense and not so siliceous; it is usually light gray in color and appears very finely granular. Still another phase is dark green and represents an arenaceous phase of the tuff. Much of the fine tuff has suffered a variable degree of mashing, so that all gradations are found from the massive rocks into sericite schists.

The microscopic character and transition into coarse tuff establishes the volcanic origin of the fine tuff. It is thought to represent a volcanic ash of rhyolitic to dacitic character, which has been indurated, silicified, and altered.

Acid coarse tuff.—The acid coarse tuff occurs associated with the acid fine tuff in northeast trending belts, separated from each other by bands of slate country. The rock is also somewhat extensively distributed as narrow intercalations and lenses within the slate belts.

In common with most of the rocks of the district, the coarse tuff is found in all gradations from a massive to a highly schistose condition. Most of the outcrops reveal their fragmental nature on fresh fracture, but with increasing difficulty in proportion as the rock is more severely mashed. The outcrops are abundant and prominent; well rounded when massive, and narrow and elongated when schistose. The weathered surface is characteristically bumpy, due to the superior resistance of the fragments, and has a yellowish or grayish color. On fresh break, the rock is seen to be composed of a dense, dark colored groundmass, containing broken crystals of feldspar and a variable number of small, angular rock fragments. The latter are usually one-half inch or less in diameter and represent several different kinds of rocks. Most abundant are fragments of a dense, light colored, siliceous rock; but pieces of slate, sometimes showing bedding planes, and of a dark colored, basic rock are not uncommon.

Along the northwestern edge of the district occurs a broad belt of sericite schists. These are light colored, extremely fissile rocks, breaking into thin sheets which are smooth and soapy to the feel and are quite soft. Upon weathering they take on the most diverse and brilliant colors, especially near mineralized zones. Associated with these occur outcrops which have not been so badly mashed but that they show their original nature and may be recognized as fine and coarse-grained acid tuffs. Every gradation can be found from such comparatively massive occurrences into the sericite schists; these are consequently considered to have been derived through dynamic metamorphism from the acid tuffs.

Those outcrops of the coarse tuff which have undergone a moderate amount of compression assume a peculiar and interesting coutour upon weathering. The rock stands up in huge almond-shaped masses, many of which are 20 feet long, 10 feet high, and 5 feet thick at the base. These are abundantly distributed in troops, as it were; and often scores may be seen, all in alignment, following the trend of a tuffaceous belt. Similar outcrops have been aptly described as resembling enormous military or cockade hats.* These probably represent slightly more massive phases of the surrounding rock, which stand up by virtue of this characteristic: enormous kernels or "augen," which, fortuitously escaping an extreme of mashing, were subsequently stripped by the forces of weathering of concentric coatings of more schistose rock, until the present elongated cores alone remained.

Fig. 2.

Fig. 2.—Huge almond-shaped outcrops of the mashed acid coarse tuff.

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*Emmons, Ebenezer, Geological Report on the Midland Counties of North Carolina, p. 52.

The coarse tuff is mostly rhyolitic to dacitic in character. Some occurrences contain a large number of andesitic fragments; and in this way a transition is made into the andesitic tuffs and breccias.

Acid volcanic breccia.—The acid volcanic breccia is practically confined to one band, about one-half mile in width, which extends through the central portion of the district. Associated with the breccia are found outcrops of the acid tuffs, flows of rhyolite and andesite, and long narrow strips of andesitic tuffs and breccias. The acid breccia is twofold in character, and comprises both a brecciated phase of rhyolite, and a very coarse tuff, with fragments predominant over groundmass and larger in size than one-half inch. The rock is locally called "mountain rock"; its outcrops are large in size and extremely abundant. Enormous bowlders up to 20 and 30 feet in diameter are frequent, and with larger, half buried masses make up rocky ridges which are almost impassable. Where most exposed, the rock becomes white and pitted upon its surface. Further weathering forms a porous, sponge-like exterior which is characteristic. Great concentrically weathered plates are at every stage of peeling off; frequently spherical shells several yards across may be pried off with a small pick.

When freshly broken, the breccia has a mottled grayish color. A great number of light colored, angular fragments make up most of the surface. Groundmass and broken feldspar phenocrysts fill in between the fragments. Irregular masses of dark green material, present in some phases of the rock, are seen on close inspection to represent andesitic fragments; these are never very abundant. In places, phenocrysts and fragments have an alignment suggestive of flow structure. Most of the outcrops are massive.

By a gradual decrease in number and size of fragments, the breccia passes imperceptibly into the rhyolite: and in almost any part of the formation isolated outcrops of the rhyolite may occur surrounded by the breccia. Part of the breccia, consequently, is considered a phase of rhyolite brecciated through flowage. Much of the breccia, however, is probably an ordinary air breccia. It is impossible to separately delimit the two phases in the field.

Rhyolite.—Rhyolite occurs in narrow, elongated areas, associated with the acid volcanic breccia, into which it grades. It is found best developed along the crest of Flat Swamp Mountain. The occurrences represent the remains of old lava flows.

The rhyolite forms prominent, rounded outcrops; and is predominantly massive and somewhat jointed. Its surface is smooth and of a light gray or white color. In places contorted and wavy lines, indicative of flowage, are visible. The rock is brittle and breaks with a conchoidal fracture into pieces with sharp, translucent edges. Upon fresh fracture, it appears black, dark green, or grayish green; with feldspar phenocrysts uniformly, though not abundantly, distributed. Some phases are exceedingly dense and can be distinguished with difficulty from the highly silicified fine tuff.

The analysis of the rock, made by the writer, is as follows:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	CO_2=Total	
74·55	10·75	1·24	2·11	trace	1·50	5·39	2·70	0·61	1·30	100·15

From this, its position in the quantitative system is calculated to be: Class I, persalane; order 4, quardofelic; rang 2, domalkalic; subrang 4, dosodic. The rock, therefore, corresponds to *lassenose.*

The rhyolite has been completely devitrified since its consolidation. According to the nomenclature proposed by Bascom,* it is an aporhyolite.

Dacite.—Dacite composes the hill east from Cid, known as Kemp Mountain. It forms here an area of oval outline, about 1 mile long and ¾ mile wide. The rock is distinctly massive and occurs in numerous, grayish-white, rounded masses, resembling the outcrops of rhyolite. In hand specimen, it is rather tough, grayish green in color, and has a slightly mottled surface, due to a few feldspar phenocrysts and to specks and small patches of biotite and chlorite. A close inspection reveals that many of the feldspar crystals are green in color from a slight admixture of epidote.

A feature of interest, brought out by the microscope, is the fact that quartz does not occur as phenocrysts. It is found, however, in the groundmass as abundant small crystals of fair rhombic outline. Similar dihexahedral quartz crystals, showing a rhombic cross section, have been described by Küch† as occurring in the groundmass of a dacite from South America.

The analysis of the rock, made by Dr. A. S. Wheeler of the University of North Carolina, is as follows:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	CO_2	Total
72·33	14·56	0·15	2·22	0·91	2·55	3·40	2·82	0·30	0·00	=99·24

In the quantitative system the rock is *lassenose*: Class I, persalane; order 4, quardofelic; rang 2, domalkalic; subrang 4, dosodic.

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* Bascom, F., The Structure, Origin and Nomenclature of the Acid Volcanic Rocks of South Mountain, Pennsylvania. Jour. Geol., vi, p. 827, 1893.

† Küch, Richard, Petrographie [from Geologische Studien in der Republik Colombia], 1892, p. 69.

The occurrence probably represents the remnant of an old surface flow, of slightly more basic nature than the flows of rhyolite. Its rounded contour on the map is due to the fact that the observer is not looking down upon the upturned edge of the flow, but more nearly upon its horizontal surface. Since there is no direct evidence of flow structure, the mass may represent an old volcanic neck or conduit, or perhaps an intrusion or sill which never reached the original surface.

The basic volcanic rocks. Andesitic fine tuff.—The andesitic fine tuff represents consolidated dust and ashes from explosive eruptions of more basic nature than those which gave rise to the acid series of rocks. Fragments are almost entirely wanting and are never visible to the unaided eye. Upon addition of these, the rock passes into the andesitic tuff and breccia, with which it is closely associated. In no place is its areal distribution of sufficient extent to show upon the geologic map. Its separate description is warranted from its analogy to the acid fine tuff.

The rock is dense and somewhat less siliceous than its acid analogue. In color it is either greenish or green mottled with purple. Outcrops are small, rounded, of grayish-green exterior, and sandpaper-like surface.

Andesitic coarse tuff and breccia.—The andesitic coarse tuff, composed of groundmass, phenocrysts, and a subordinate number of fragments; and the andesitic breccia, with predominant and larger fragments, are described together. Their intimate association makes it impossible to separately map the two.

These rocks form long, narrow strips and broader lenses of important areal extent, alternating with the areas of slate and the acid series of volcanic rocks. They range all the way from massive varieties, made up almost wholly of green fragments, to greenstone schists, which in themselves contain little evidence of their fragmental nature. The outcrops are abundant and prominent; when massive, they are low and well rounded; with increasing degree of schistosity, they become elongated and narrow, and resemble much in shape great inverted wedges. Only a few extremely schistose occurrences fail to have a humpy weathered surface, which reveals the fragmental nature of the rock, even when this feature is not observed on fresh fracture.

The massive rock is heavy, tough, dark green, and composed almost entirely of dark green fragments up to three-quarters of an inch and larger in diameter. Dark green material, containing feldspar phenocrysts, fills the spaces between the fragments. More schistose varieties appear less fragmental; the fragments have been converted into areas of greenish secondary minerals.

Often the mashed rock is somewhat lighter in color than the massive varieties.

The microscope reveals the fragments to be of at least four kinds: (1) fragments of an andesitic flow rock, with a pilotaxitic groundmass of a fluidal texture; (2) fragments of andesitic rock without trachytic arrangement of the feldspar laths; (3) fragments of an amygdaloidal andesite; and (4) fragments of an acid rock, probably a tuff.

The wide distribution of the type of rock just described, and its diversity of contained fragments, suggests the great complexity of the volcanic period during which it was formed. There were undoubtedly many alternations between outbreaks of acid and comparatively basic magmas.

Andesite.—Andesite is of limited occurrence within the district. It forms several narrow strips and lenses of small areal extent, which represent the remnants of old flows. The rock is massive and mostly porphyritic. One occurrence is amygdaloidal and dotted with small rounded and oval areas of greenish material, representing the vesicles of a surface lava subsequently filled with infiltrated material. The outcrops are not large, but are fairly abundant, and are usually rounded.

The porphyritic andesite is a medium to fine-grained rock, varying in color from a grayish green, or epidote green mottled with blue, to a dark bluish purple. All variations contain small green specks and masses of epidote. Except in the densest specimens, the rock is easily seen to be porphyritic; the phenocrysts are feldspar laths of variable abundance.

The amygdaloidal phase is an epidote-green rock, abundantly dotted with rounded and elliptical amygdules, varying in diameter up to 4^{mm}. These are filled with material of a darker green color, which in most cases is epidote with chlorite, but sometimes in part calcite. Near the surface the material filling the cavities has weathered out, giving to the rock a honeycombed appearance.

The analysis of the rock, made by the writer, is:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	CO_2	Total
66·28	10·62	6·41	2·11	1·15	3·17	6·09	1·73	0·61	1·47=	99·64

From this, its position in the quantitative system has been calculated to be: Class II, dosalane; order 4, quardofelic; rang 1, peralkalic; subrang 4, dosodic. The rock corresponds to *pantellerose.*

The rock on the whole is a very alkalic andesite. Certain phases have a strong trachy-andesitic stamp.

Dike rocks. Gabbro.—Gabbro occurs widely and abundantly distributed in the form of dikes, trending in a northeast-southwest direction. In size these vary from one-eighth mile in width and 3 to 4 miles in length to ones indicated only by the presence of a few bowlders. The rock shows upon the surface as rounded, yellowish bowlders, ranging in size up to 10 feet in diameter, and distributed in lines following the trend of the dikes.

The directions of the dikes in all cases coincide with the schistosity of the formations in which they occur. Also, the gabbro is itself unmashed. The schistosity is therefore considered to have been developed prior to the introduction of the dikes and to have been, as an easy line of yielding, a controlling factor in their entrance.

The contacts between dikes and adjacent formations are much obscured by weathering, so that it is impossible to discern any contact effects. The deeply weathered nature of the contacts, however, bespeaks a zone susceptible to alteration and doubtless rendered so by contact action. Jointing is well developed, and of such a nature as to suggest the operation of a compressive force after the introduction of the dikes.

The gabbro is a greenish-gray rock, of medium grain and homogeneous texture, in which crystals of green hornblende and areas of opaque feldspars may be recognized. The microscope reveals that the hornblende is uralite, secondary after pyroxene, and that the feldspar has been completely changed into saussurite, which represents an original plagioclase rich in lime. The rock is tough and heavy, and is very susceptible to weathering. In point of age, it is the second youngest rock in the district, since it cuts the other formations and is itself cut by dikes of diabase.

Diabase.—The diabase forms narrow dikes uniformly, though not abundantly, distributed throughout the district. It shows upon the surface as narrow lines of small rounded bowlders of an iron-rust color, locally called "niggerheads". The dikes vary in size from a few feet in width and a few yards in length to the largest, which is about 100 feet in width and slightly over a mile in length. The majority conform to the former dimensions. In trend they usually vary from N. 30° W. to N. 30° E. The trends of the dikes coincide with important joint directions.

The diabase is a massive, fine-grained, dark blue rock, very tough and with a waxy luster on fresh fracture. Upon examination it is seen to be a closely knit aggregate of dark-colored minerals, among which striated feldspars may be distinguished from the ferromagnesian minerals. Although the rock is high in olivine, this constituent cannot be megascopically distinguished from the augite. The mineral composition, or mode, determined by the Rosiwal method,* gave : 45·6 per cent

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* Rosiwal, Verh. Wien. Geol. Reichsanst., vol. xxxii, p. 143 ff., 1898. Cf. Cross, Iddings, Pirsson, Washington, The Quantitative Classification of Igneous Rocks, p. 204.

plagioclase; 35·3 per cent augite; 17·4 per cent olivine; and 1·7 per cent magnetite.

The analysis, made by Dr. A. S. Wheeler, is:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	CO_2	Total
47·66	19·24	1·83	8·67	10·79	9·91	1·14	0·26	0·06	0·00	=99·56

From this its position in the quantitative system is calculated to be: Class III, salfemane; order 5, perfelic; rang 5, percalcic; subrang, not needed. The rock corresponds to *kedabekase.*

The diabase is the youngest rock in the district and is probably of Triassic age. As is well known, dikes of fresh olivine diabase have a widespread occurrence throughout the Piedmont Plateau, and in many places may be traced into areas of Triassic sandstone.

Structural features.

Folding.—The region has been squeezed into great folds during a period of severe compression, the most evident effect of which has been the mashing of many of the rocks into schists. The folds may not be directly observed, but their presence is inferred from three concurrent lines of evidence.

1. Bedding planes, which indicate a former horizontal extent, often depart from this direction, and have a variable dip either to the northwest or to the southeast, and at times are even vertical. Were these sufficiently well preserved, they alone would indicate the exact nature of the folding; but they are much obscured by schistosity and weathering, so that only here and there can a measurement be obtained. Certain generalizations, however, may be made. Bedding planes are predominantly horizontal along certain northeast-southwest lines in massive formations; and tend to be vertical or nearly so in the badly mashed belts.

2. The surface outlines of the formations, best seen on the geologic map, are indicative of folding. In general, the formations may be divided into two classes: first, those which appear upon the surface as long, narrow stripes, which gradually pinch out at the ends and never end abruptly against other formations; and second, those which occur in broad lenses and oval areas, of little or no elongation, and often ending abruptly against other formations. Many of the narrow bands are flow rocks or tuffs and breccias, which must have been deposited in layers or beds of horizontal extent. Their surface outline seems to preclude any other possibility than that they are the upturned edges of such beds, which now intersect the surface vertically, or nearly so. Broader lenses and oval areas, although often composed of the same rock as the narrow stripe,

can hardly have the same underground relations. If those, too, represent the edges of beds, and consequently expose their cross-section, the abrupt endings of such formations and the great stoutness of many of the lenses are difficult features to explain. Besides, the predominance of horizontal bedding near such formations is quite incompatible with such an idea. A satisfactory explanation lies in the consideration of these areas as occurring on the crests of great folds. This position allows of a most irregular surface slope, with abrupt endings against other formations, when planation has exposed a particular bed to view; and is, moreover, in accord with existing bedding planes.

3. The relation between schistose and massive formations throws further light on the structure. Schistosity is not developed alike in all parts of the area; it appears to have been the result of a selective action, so that some belts are predominantly massive, whereas others are strongly schistose. This cannot be explained by a difference in the nature of the formations; for the same formation may in one place be massive, and in another, badly mashed. The position of a rock mass, therefore, is apparently a much more important factor in determining its degree of schistosity than its lithologic character. It follows, accordingly, that, although the region as a unit was subject to compression, some portions were so situated as to escape any important effects of such a force. The crests of folds would afford positions favorable for the transmission of a great compressive force without important molecular adjustments; the limbs would involve a greater slipping between beds and consequently be susceptible to the greatest degree of mashing. This assumption best fits the facts observed.

The three lines of evidence concur, then, in making pretty conclusive proof that the region is folded. The exact nature of the folding is a more difficult thing to determine. Yet an application of the same three principles indicates that the region very probably represents in general two anticlines and one syncline, the axes of which extend in a northeast direction in agreement with the schistosity. Flat Swamp Ridge is considered the trough of the syncline; and the two corresponding anticlines are near the northeast and southwest borders, respectively, of the district.

Consequent upon the major folding, a series of subordinate crumplings and crinklings were of necessity formed; but these have been so obscured by weathering and other changes as to baffle detection. Their presence is only indicated by an occasional bedding plane out of accord with other measurements in its vicinity.

It is probable, also, that the major folds are not absolutely horizontal, but pitch slightly, so their crests form wavy lines. No direct measurements of pitch can be obtained, but inference as to its nature may be made from the way in which certain formations end abruptly against others, as if dipping beneath them. A further evidence is the occasional discordance between trend of bedding and of schistosity, indicative of a complexly folded region.*

In addition to these major and minor directions of folding, whose axes lie in a horizontal plane, the whole region has, perhaps, been slightly bent around a vertical axis. A glimpse at the geologic map will disclose the tendency of the schistosity to form an arc-like arrangement; in general, varying from a northeast trend near the river to a more northerly direction as the upper limits of the map are approached.

Mashing.—It has been suggested in the previous section how schistosity has been induced upon much of the region by the same compression which occasioned folding, and how this has been more prominently developed on the limbs of the folds than on the crests or in the troughs. A further deduction, however, may be made from the nature of the schistosity; that is, the direction along which the compressive force acted. The average trend of schistosity is N. 50° E. Theoretically, therefore, the compression acted along a line passing N. 40° W., as the effects of compression are at right angles to the force.† This figure must not be taken as exact, for other factors would complicate the result; but it is approximately true.

The average dip of the schistosity is about 70° to 80° to the northwest, with extremely few cleavage planes dipping to the southeast. This is significant. It suggests that the folds are not upright; for in such a case approximately half of the schistosity should have a dip to the southeast. Thus there is evidence for believing that the folds are slightly inclined, their axial planes agreeing in a general way with the average dip of the schistosity. This view is consistent with the arc-like arrangement of the formations, which in itself implies a slight overriding of the upper crust and an axial dipping of the folds towards the center of the arc.

The northwest dip of cleavage planes and northwest-facing concavity of the arcs is the opposite of conditions holding in the Appalachians. This may be due either to some undetermined local cause, or to an actual reversal of the relations between land and sea obtaining in the Paleozoic; so that in

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* Van Hise, C. R., Principles of North American Pre-Cambrian Geology. 16th Ann. Rept. U. S. Geol. Survey, 1895, p. 629–630.

† See in this connection Haug, Emile, Traité de Géologie, vol. i, p. 227, 1907.

the case of the present area, the higher segment or land mass was to the northwest, whereas in the case of the Appalachians, as is generally accepted, the higher segment or "hinterland" of Suess was to the southeast. The district under consideration, however, is too limited in size to afford widespread generalizations on this point, unless corroborated in the future by other observations in the slate belt.

Jointing.—Joint planes are distributed throughout the district in all formations, but are most abundant in areas of massive rocks. In general, the degree of jointing decreases with increased schistosity: the two features seem to be complementary. Where bedding is horizontal, jointing is invariably well developed.

These features indicate that the jointing is largely the result of the compressive force of folding. Rock masses situated on the crests or in the troughs of folds escaped to a large degree the effects of mashing, but in transmitting the force were themselves broken into blocks bounded by joint planes.

The following conclusions are drawn from a graphical plotting of the joints. The jointing is grouped into four important sets, in their order of importance, as follows:

N. 5° W. to N. 30° W.
N. 65° W. to N. 85° W.
N. 15° E. to N. 35° E.
N. 70° E. to N. 85° E.

There is no important difference in the jointing in the slate and in the other formations. In massive formations there are no important joint planes parallel to cleavage planes in schistose formations. There is no evidence for believing any important jointing on crests of folds to be due to tension: joints from such a cause would be parallel to the schistosity developed on the limbs of the fold.*

All jointing in the region is not considered the result of a single period of compression. There is doubtless jointing, also, from other subsequent earth movements.

Faulting.—While there is at no place conclusive evidence of faulting on an important scale, a number of probable faults have been indicated on the geologic map. These cannot be verified by field observation; but their presence is suggested by the abrupt ending of certain formations, as if cut off by dislocations, and in cross-section by the failure of bands to be repeated on the corresponding parts of folds. The smaller faults have a general parallelism to one another, and to Fourmile Branch, which pursues a remarkably straight course

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* Van Hise, C. R., Principles of North American Pre-Cambrian Geology. 16th Ann. Report, U. S. Geol. Survey, 1895, p. 669.

for six miles and agrees in direction with two large diabase dikes. They are also roughly parallel to the strike of a profound fault a few miles to the west, which Laney* has shown to separate the slate series from a large area of igneous rocks.

A large overthrust fault has been indicated as extending along the eastern border of Flat Swamp Ridge in a northeast direction and becoming northerly in trend near the upper borders of the map. Its presence seems necessitated by the way in which broad belts of rock appearing on the western slope of Flat Swamp Ridge are not repeated on its eastern declivity, as would be expected on the two limbs of a syncline. Either, then, beds one-half mile or so in thickness must thin out along their dip in the course of a mile or they must be abruptly cut off by a fault. A glance at the cross-section will make this point clear.

Fig. 3.

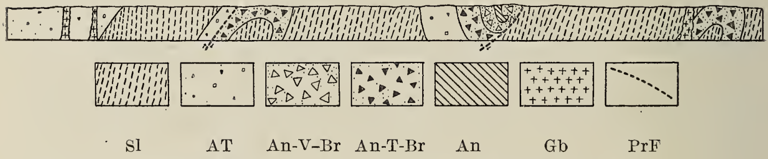

Fig. 3. Cross-section along the line AB of the geologic map.
Explanation of contractions: Sl, slate; AT, acid tuff; An-V-Br, acid volcanic breccia; An-T-Br, andesitic tuff and breccia; An, andesite; Gb, gabbro; Pr.F, probable faults.

The faulting is probably the result of the same compressive force which induced folding, schistosity, and jointing. It is unnecessary to bring in a second great earth movement to explain this structure. Yet it is possible that the coming to place of great granitic batholiths a few miles to the west may have exerted sufficient compression to occasion overthrust faulting.

Interpretations of structure.

Most probable interpretation.—The reasons have already been presented for believing the region to be made up of a series of inclined folds, whose axial planes dip steeply to the northwest. This interpretation is represented on the accompanying cross-section.

In a region, such as the one under consideration, in which the structural features are so obscure and difficult of access, a diagram can only attempt to express in a generalized manner the actual conditions.

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* Laney, F. B., The Gold Hill Mining District of North Carolina. A Thesis, Yale University, 1908, p. 112.

In the cross-section given no minor crumplings are indicated on the major folds. Such undoubtedly exist, but they are omitted both for the sake of simplicity and because their nature is not known. The thickness of those beds whose cross-section is in no place exposed upon the surface is entirely hypothetical. If it be attempted to trace out each formation as it is successively brought to the surface by the folding, it will be found that the beds do not always match on the opposite limbs of the folds. This is understood, if it be accepted that the original horizontal extent of the formations consisted of a complicated interfingering of beds and lenses, and was not a succession of regular beds of the same thickness thoughout their lengths. In such a case folding would not necessarily repeat similar beds on corresponding part of folds. Along Flat Swamp Ridge, however, this explanation seems inadequate, inasmuch as beds of great thickness must pinch out with extreme rapidity in order to avoid repetition. To obviate this difficulty, an overthrust fault has been introduced as stated, as a simpler explanation. The arc-like surface trace of this supposed fault-plane renders it probably an overthrust consequent upon the northwest compressive force of folding. The fault-plane may itself be folded, depending upon whether the slip occurred at the beginning or near the end of the period of folding. The latter conception is preferable, because simpler.

Alternate hypotheses.—Although the interpretation of structure given appears to best fit the facts, some alternate hypothesis, especially in regard to the subordinate features, may be mentioned.

As suggested in previous paragraphs, the entire structure may be explained without the use of faults.

A portion of the rocks may have been brought into the region by an overthrust fault; and these subsequently interfolded with the regional rocks.

The region may possibly represent a series of isoclinal folds, with parallel limbs.

That the region may not be folded and represents a very thick deposit, which has been tilted and whose edge is now cut across by the plane of erosion, seems hardly a possibility.

Discussion of geologic history.

The geologic history of the Cid district may be considered as having its beginning during a period of volcanic activity of long duration. During this time there were innumerable alternations between quiet upwellings of lava, forming surface flows; explosive activity on an enormous scale, piling up to great thickness deposits of tuffs and breccias; and periods of comparative quiescence, accompanied by some weathering and erosion and the deposition of the slates. Between successive outbreaks, the magma probably underwent a certain degree of differentiation; so as to give rise to acid rocks at one time, and comparatively basic rocks at others. It seems evident that there were frequent swings between two not very diverse extremes, and that at no time did the product depart far from the average type—a rather acid rock high in soda. Perhaps each important outbreak poured forth rhyolitic, intermediate, and andesitic materials.

It would be impossible to picture the details of this volcanic activity. It is suggested, however, that the outbreaks were largely eruptions along fissures, breaking up through the series of already formed horizontal rocks at frequent points in the entire volcanic region.

All of the slate and much of the fine tuff give evidence in bedding planes of deposition by water. The coarse tuffs and breccias may be air-laid or water-laid, or both. The flows may have taken place upon the surface of the land or under water. Possibly the entire series represents an off-shore deposit, with submarine volcanic activity alone or accompanied by outbreaks upon the shore. Or the region may represent a river flood-plain or delta deposit.

It is believed from chemical evidence that the slate material was transported from no great distance. Hence a probable view is to consider the volcano-sedimentary series a basin deposit, the material for which was derived from beneath an area of limited extent, and the thickness of which was limited only by the depth of the magma reservoir and the amount of material extruded. Thus by isostatic sinking of the crust block capped by a layer of sedimentary and volcanic rocks, as more material was forced up through it and deposited upon its top, a series of great thickness could have been formed, without drawing materially upon the surrounding country for sediments, and conversely without bestowing evidences of its nature upon regions not within its own confines.

However laid down, the tuffaceous and sedimentary rocks must have undergone cementation or consolidation before they were capable of being thrown into folds. This process doubtless accompanied the formation of the deposits.

No evidence is afforded for estimating the length of time which intervened between the formation of the rock series and its folding. It may be that the compression put an end to the constructive epoch; or it may equally be that this force was long deferred.

Following the folding after an unknown interval, a great number of gabbro dikes were insinuated into the region. These represent either the outliers of an independent gabbro batholith or the differentiated off-shoots from a large magmatic reservoir of more acid nature; and are probably related to great intrusive masses of granitic, dioritic, and other massive coarse-grained igneous rocks occurring a few miles to the west.

The coming to place of the igneous masses, which adjoin and probably undermine the district, inaugurated a period of activity of circulation; during which the rocks were mineralized, in part by valuable ores, and universally by pyrite and pyrrhotite; many formations enriched "en masse" by silica; and a large number of quartz veins left along lines of major circulation. The amount of material introduced seems to preclude any but a magmatic source. It is not known to what proportional extent, if any, the materials were contributed by the gabbro or by the large granitic masses. From the great amount of silica introduced, and from the acid character of the gangues, it is likely that the granite was the dominant source.

The first event of practically known age is the introduction of diabase dikes in Triassic time. There is no evidence for estimating the length of the interval between the period of ore deposition and the coming to place of the diabase.

And finally, the forces of weathering and erosion, although operative since the region was first elevated by folding, have been especially active from the introduction of the diabase to the present. This period then is dominantly one of planation and rock decay: to such an extent, indeed, that the region has been reduced once to an approximate base-level, and although rejuvenated by uplift, is again approaching that state.

Summary of geologic history.

Pre-Cambrian (?) 1. Building up of the volcano-sedimentary series. Alternation of volcanic activity and periods of quiescence.

2. Consolidation of the series.

3. Operation of a compressive force, throwing the whole formation into folds, and inducing schistosity, jointing, and probably faulting.

Paleozoic (?) 4. Approach of a mass of igneous rock, announced by the insinuation of gabbro dikes into the region.

5. Passage of solutions, depositing iron ores and silica, and forming quartz veins and mineralized zones.

Triassic, 6. Introduction of diabase dikes.

Post-Triassic, 7. Period of weathering and erosion.

Thickness and age of the slate series.

Thickness.—Nothing definite can be said about the thickness of the volcano-sedimentary series. From the cross-section, however, it appears probable that the series is from 2 to 4 miles thick. This estimate is given by no means as a final figure, but with the hope that future work in the same province may turn it into something more definite, corroborative or otherwise.

Age.—Again, nothing final can be said about the age of the slate series. It has generally been considered to be Pre-Cambrian. Volcanic rocks of a somewhat similar nature in the South Mountain region of Pennsylvania occur beneath Cambrian sandstone.* As there is no evidence to the contrary, the present series is provisionally correlated with the Pre-Cambrian.

Acknowledgments.

In conclusion, the writer wishes to acknowledge his great indebtedness to the advice and previous work of Dr. F. B. Laney, whose report on the adjoining Gold Hill District, containing many of the results herein set forth, is now in press. Also the author desires to thank Professor Joseph Barrell for suggestions in regard to the structure, and Professor L. V. Pirsson for interest and advice during the entire investigation and the preparation of this article.

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* Williams, G. H., The Volcanic Rocks of South Mountain in Pennsylvania and Maryland, this Journal, v. xliv, 493–494, 1892.

ART. XXV.—*On the Electric Arc between Metallic Electrodes;* by W. G. CADY. Third Paper.*

IV. THE PROPERTIES OF GLOW-ARC OSCILLATIONS.

IN the second paper it was shown that when a discharge at small current takes place under an impressed e.m.f. of several hundred volts from a metallic cathode, in a gas which is preferably a mixture of hydrogen and acetone vapor, rapid electrical oscillations are generated, of a frequency depending essentially on the electrical constants of the portions of the circuit in the neighborhood of the discharge tube. The nature of the pulsations seems to be a series of rapid changes back and forth between arc and glow.

In the following paragraphs the properties of these oscillations, as far as they have been examined, will be discussed.

§15. *Apparatus.*—Preliminary observations showed it to be desirable to employ a discharge tube with electrodes of as simple a form as possible, in order that the oscillations might not encounter a needless amount of resistance or of self-inductance close to the discharge itself. To this end, brass rods *AA* (fig. 1), 3^{mm} in diameter, were extended through corks in the ends of a glass tube about 10×3^{cm}. The electrodes usually employed were discs about 1^{cm} in diameter, with slightly rounded faces. A number of discs of different metals but of the same size and shape were made, which could be screwed on to the rods.

A mixture of hydrogen and acetone vapor was led in through the glass tube *C* and out again at *D*, where it burned in a minute flame. *E* was a small side-tube, closed with a cork, for the insertion of a brush for cleaning the electrodes. As only atmospheric pressure was used, no special sealing was necessary, other than a little soft wax.

The positive electrode was hardly attacked at all by the passage of the current, but the cathode showed a small cavity at each point from which the discharge had taken place. It was necessary to rotate the cathode slightly from time to time, as well as to adjust the length of discharge (a few tenths of a millimeter) with great care. Hence one of the brass rods was sealed into a glass tube *F*, which was connected by means of a straight ground-glass joint to a second tube *G*, the latter being sealed into the cork. By having the two rods slightly eccentric in their mounting, and by rotating *F* or moving it slightly in or out, very delicate adjustments were possible.

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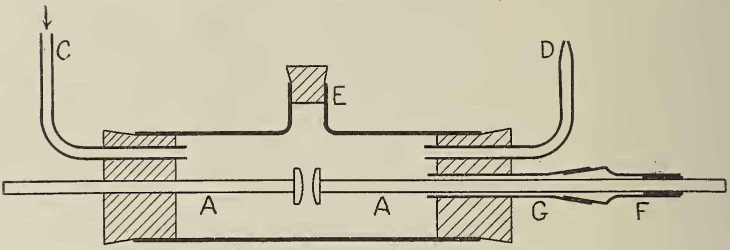
* Continued from this Journal, vol. xxviii, p. 102, 1909. The paragraphs are numbered consecutively in the second and third papers.

§16. As long as the circuit on at least one side of the tube was free from too large self-inductance or resistance for a few meters from the discharge, good oscillations could be obtained. During most of the experiments large copper wires extended from the tube about one meter apart for a distance of about 15^m with as few bends as possible. At the farther ends of these wires were first, coils of large self-inductance, then the regulating resistances, ammeter shunt, and electromotive force, the latter consisting of a small 650 volt generator, in series with which were connected at times about 350 volts additional. The currents used ranged from 0·0025 to 0·25 amp., the strongest oscillations being produced at about 0·1 amp.

Fig. 1.



A voltmeter connected across the discharge indicated, during oscillations, about 215 volts when the current was 0·1 amp. This value, however, cannot be depended upon, for the presence of the voltmeter as a shunt across the arc greatly diminished the intensity of the oscillations (cf. §31). The true value of the mean discharge potential was obtained from a knowledge of the current, e.m.f., and external resistance, and it proved to be about 280 volts under conditions similar to those described above. This is intermediate between the voltage drop usually found for an arc and that for a glow.

When the electrodes were touched together and then separated slightly, the discharge formed a minute spot of light between their nearest portions. It was of a bluish color, not very bright, and differed in appearance from either an arc or a glow. The presence of oscillations penetrating through the circuit as far as the self-inductance coils was shown by the heating of a bolometric detector in the neighborhood, or by the brightening of a pilot lamp in the discharge circuit (see §18).

§17. *Alternating current as source of energy for oscillations.*—Considering the shortness of the discharge-gap, it was thought that a moderately high alternating e.m.f. might suffice to maintain the discharge.* Accordingly the voltage of the 60-cycle mains was stepped up to about 880 volts and used in place of the usual direct-current supply. With an effective current of about 0·06 amp., oscillations of fair intensity were produced, with which most of the experiments described below could be performed.

This use of the alternating current to produce high-frequency oscillations suggests that the effect described by Duddell† in his recent paper on "short spark phenomena" may be due to pulsations of the kind described in the present article.

§18. *Properties of the oscillations.*—The following simple experiments illustrate in a striking manner the properties of these oscillations. Unfortunately all attempts at increasing the output of energy have been fruitless, for the maximum potential difference is only that of a glow discharge, and the discharge degenerates into a steady arc if the current is increased much above 0·2 amp. A close-coupled resonance transformer reacts upon the discharge, reducing the oscillations. Still, for purposes of demonstration the oscillations may find a certain field of usefulness, for they exhibit the chief properties of high-frequency alternating currents with extremely simple apparatus. The supply e.m.f. may be alternating, but it is better direct, and the latter is here assumed.

(*a*) Connect in series with the tube a direct-current ammeter and an incandescent lamp of about 0·5 amp. capacity. When the electrodes are touching the ammeter reads, say, 0·2 amp. and the lamp glows dimly. On separating the electrodes the ammeter indicates a diminished current, but if oscillations are present the lamp burns brightly, showing that *the effective alternating current is greater than the direct current supplied by the generator.* From the increase in brightness of the lamp a rough estimate can be made of the efficiency of conversion of direct into alternating current. A miniature lamp, or one of several hundred ohms resistance, may be used equally well. In nearly all of the work an 8-volt 2-candle power lamp was kept in series with the discharge tube, and it was found to serve as an excellent indicator of the presence of oscillations.

(*b*) Connect a few turns of heavy wire in series with the tube, and in parallel with this coil place a high-resistance lamp. The latter glows brightly. It was by this means that the first estimate of the frequency of the oscillations was made, in terms of the self-inductance of the coil, and of the resistance and volts (estimated from the light) of the lamp.

(*c*) Connect in series with the tube a miniature lamp, then a resistance of several hundred ohms, and finally a second

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* Cf. Peukert, Elektrot. Zeitschr., xxiii, p. 562, 1908.

† Duddell, Proc. Phys. Soc. London, xxi, Part III, p. 275, 1909.

miniature lamp. The first lamp glows brightly, the second little or not at all, showing that the oscillations have been absorbed by the high resistance.

(*d*) Substitute a coil of self-inductance, but of low resistance, for the high resistance in (*c*). The result is the same as before, owing to reflection and absorption of the waves by the self-inductance. These experiments explain the fact that the remote parts of the circuit are entirely devoid of oscillations. Thus, if there are connected in series with the discharge a small lamp, a few meters of straight wire, a second lamp, and a large self-inductance, the lamp nearer to the tube will brighten up under the oscillations, while the other remains dark, showing that a node of current is located at the self-inductance, as if at the end of an open oscillator.

I have repeated these experiments, using a hot-wire ammeter instead of lamps, and have thus explored various parts of the circuit for oscillations. An example of such observations is shown in Table I. Each set of readings corresponds to a different external resistance. i_0 is the current, in amperes, given by the generator, i that indicated by the hot wire close to the discharge, and i_1 the effective alternating current, which in one case is nearly three times as large as the direct current supplied.

Table I.

i_0	i	$i_1 = i - i_0$
·063	·243	·180
·093	·265	·172
·124	·284	·160

(*e*) If a coil of moderately large self-inductance is connected close to the tube on each side, the discharge becomes irregular and noisy, and no high-frequency oscillations appear. There seems to be a critical value of the self-inductance at which the oscillations suddenly cease. The cessation of oscillations apparently shows that the glow-arc pulsations cannot take place above a certain frequency.

(*f*) Hold one terminal of an incandescent lamp of high resistance in the hand, and touch the other terminal to the discharge circuit near the tube. The lamp lights up, the light being brighter when the lamp is on that side of the tube nearer to a self-inductance, as it is here that the antinode of the e.m.f. wave occurs.

(*g*) By means of a frequency meter with a range of from $0{\cdot}2\times10^6$ to 5×10^6 periods per second, the fundamental vibration and its upper harmonics can be detected. The best method is to allow a coil of a few turns in the discharge circuit to act inductively on a second coil in fairly close coupling with it. If the second coil is in series with a small lamp and a variable condenser, then as the capacity is slowly varied the lamp can sometimes be seen to light up three or four times, as successive harmonics are passed. The lamp sometimes glows more brightly than a similar one in the discharge circuit.

(*h*) If the coupling in the last experiment is close, then on closing the resonating circuit it is found that the direct current from the generator is reduced, showing that the secondary circuit has reacted on the primary.

§ 19. *Energy and efficiency of the oscillations.*—The following experiment was performed in order to discover how large a percentage of the direct current energy expended in the discharge could be converted into the energy of electrical oscillations. Two 4-candle power 110 volt incandescent lamps of about 700 ohms resistance each were connected in the discharge circuit, one on each side of the tube. They absorbed nearly all the energy of the oscillations, and glowed more brightly when the discharge passed than when the electrodes were touching.

The total power absorbed by the lamps is given in the first column of Table II. It was estimated from the brightness of the lamps. In the second column are recorded the watts expended in the lamps by the direct-current component, obtained by multiplying the square of the generator current (last col.) by the lamp resistance. The difference between the first and second columns gives the watts of alternating current power consumed by the lamps. The watts supplied by the generator to the discharge (neglecting the external resistance) are given in the fourth column, while the fifth column shows the efficiencies, obtained by dividing col. 3 by col. 4. It will be observed that *the highest efficiency recorded is 66 per cent.*

TABLE II.

Watts in lamps			Watts supplied to arc	Per cent efficiency	Generator current
Total	d. c.	a. c.			
13·8	5·4	8·4	18·0	46	·06 amp.
19·6	7·4	12·2	21·2	57	·072 "
25·0	9·0	16·0	24·2	66	·082 "
36·0	20·4	15·6	34·5	45	·125 "

§ 20. *Determination of the frequency.*—The following resonance method was used in determining the frequency of the oscillations. In the main discharge circuit, about 30–50^{cm} from the tube, was a coil of wire which in most of the experiments consisted of six turns, having a diameter of 22^{cm}. Its self-inductance was about 20,000^{cm}. This primary coil acted inductively on a secondary coil at varying distances from it. The secondary coils used had self-inductances varying from 790^{cm} to 1,170,000^{cm}.

In series with the secondary coil was an adjustable condenser of zinc plates separated by sheets of glass, the whole immersed in kerosene. The secondary circuit contained also a hot-wire ammeter of about two ohms resistance. As detecting devices a thermo-element, and also a bolometer in a tertiary circuit loosely coupled with the secondary circuit, were tried, but neither method gave as good results as the hot wire in the resonating circuit itself. For the purpose in hand, the damping caused by the resistance of the hot wire was not serious.

According to the method just described, it will be seen that the e.m.f. induced in the resonating circuit is proportional to the current in the discharge circuit. That is, if M represents the mutual inductance between the two coils,

$$e_2 = M \frac{di_1}{dt}.$$

Since this expression involves the frequency, it follows that

$$e_2 = ki_1 f, \qquad (1)$$

where k is a constant.

By using secondary coils of varying self-inductance and each time adjusting the capacity for resonance, the fundamental vibration together with its upper harmonics could be investigated for frequency, and to some extent for intensity. It was always found that the hot-wire deflections corresponding to the fundamental vibration were very small. This agrees with the relation expressed in equation (1), since f has its smallest value for the fundamental, and the hot-wire deflections are proportional to the square of e_2. Remembering also that the wave-form of the oscillations is certainly very complex, it is evident that the deflections corresponding to some of the upper harmonics will be much greater than those for the fundamental. I found it necessary to use very close coupling in order to detect the fundamental at all. Loose coupling could be used for harmonics from the third to the ninth, while above that the coupling had to be made close again, on account of the diminishing value of i_1.

§ 21. When the capacity of the discharge circuit was increased by touching a piece of metal about 10^{cm} square to a point near the discharge tube, the frequencies were slightly lowered, as would be expected.

§ 22. Introducing a coil of a few turns of wire into the discharge circuit lowered the frequency. A coil of larger self-inductance greatly increased it, since the penetration of the oscillations was stopped by reflection from the coil.

§ 23. Varying the supply e.m.f. from 600 to 1000 volts had no effect upon the intensity or frequency, as long as the current remained unchanged. Reversing the direction of the current also had no effect.

§ 24. Increasing the current increased the frequency, as illustrated in the following table, in which the last column

TABLE III.

Generator current	Frequency	Deflection
0·09 amp.	$8{\cdot}6 \times 10^5$	49^{mm}
0·10 "	8·7 "	104
0·11 "	9·1 "	109
0·12 "	9·3 "	56
0·13 "	9·45 "	39

gives the hot-wire deflections, serving as a measure of the intensity of the oscillations. The frequency observed is that of the third harmonic. If the intensity of the oscillations diminished with increasing current, it would be possible to account for the increase in frequency on the supposition that with decreasing intensity the oscillations penetrated less far into the circuit, i. e. that the effective length of the "oscillator" was less. But the third column shows that the intensity was greatest for a current of 0·11 amp., and diminished as the current increased or decreased (§ 8). The change in frequency must be due to the changing resistance of the heated vapor, which affects the frequency according to the formula

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}.$$

An increase in the discharge current, decreasing the resistance R between the electrodes, must clearly raise the frequency. The apparent mean resistance, derived from the measurement of current and e.m.f., varies under different conditions between 2000 and 5000 ohms. It is hardly conceivable that the resistance for oscillations can be as high as this, but it is evident, at least, that the discharge possesses a high resistance, which changes markedly as the current is varied.

As no means suggested itself for measuring directly the resistance of the discharge for oscillating currents, I tried the effect of inserting a large known non-inductive resistance (graphite rod) in the circuit close to the discharge. This experiment failed to throw light on the problem, for when the resistance was large enough to modify the frequency at all, it absorbed the oscillations and reduced their penetrating power to such an extent that the frequency was increased instead of decreased. The resistance of the discharge would not be expected to limit the penetration of the oscillations to a like extent, since the discharge is the source of the oscillations and they are propagated in each direction from it.

It was difficult to determine the effect on the frequency of varying the length of the discharge, for this length was limited by the available e.m.f. to about one millimeter, and it became continually shorter as the discharge passed, on account of the deposits of carbon dust on the electrodes. One would expect an increase of length to cause an increase in resistance, and thus to diminish the frequency of the oscillations. It can only be affirmed that the possible variation in length was over too small a range to affect the frequency appreciably.

§ 25. *Systems of harmonics.*—Owing to the impossibility of keeping the state of the discharge and intensity of current constant long enough to obtain data for a full resonance curve, only incomplete groups of harmonics can be shown, obtained at different times, and under different conditions. The discharge, and consequently the frequency, fluctuated so much that the resonance curves were considerably flattened, as if the oscillations had been damped. But in one or two signal instances (see § 29), when the discharge was unusually steady, curves for one or two frequencies of great sharpness were obtained.

In the following table some representative groups of harmonic frequencies are shown. The figures in the first two

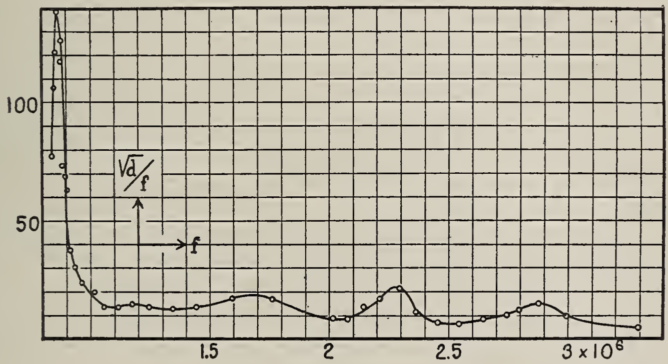
TABLE IV.

Fundamental	Observed frequency	Ratio	No. of harmonic
0·255	0·25	0·98	1
	0·465	1·82	2
	1·02	4·0	4
	1·32	5·18	5
	1·82	7·1	7
	2·22	8·70	9
0·237	0·237	1·0	1
	1·4	5·91	6
	1·68	7·10	7
	2·9	12·2	12
	3·7	15·6	16(?)
0·22	0·46	2·09	2
	0·66	3·00	3
	0·84	3·83	4
	1·12	5·09	5
0·288	0·87	3·02	3
	1·18	4·10	4
	1·70	5·90	6
	2·30	7·99	8
	2·88	10·0	10

columns give the frequencies in millions per second. The harmonic relation is in general clear, considering that in many cases the settings were difficult and resonance ill-defined. The value of the fundamental given in the first column is that which best satisfies the observed upper harmonics. Owing to the looseness of the coupling, the fundamental could not be directly observed in all cases. As a test of the accuracy, the third column contains the quotients obtained by dividing the observed frequencies by the fundamental. These quantities should be integers representing the number of the harmonic.

The differences between the wave-forms of the various groups are due to differences in current and changes in the electric circuit.

Fig. 2.



§ 26. The results of the last group are also represented in fig. 2, in which the resonance curve is drawn. All the observations were made within the range of the adjustable condenser, the same secondary coil and the same degree of coupling being preserved for all. The ordinates are not observed deflections of the hot wire, but are in arbitrary units proportional to the intensity of the primary oscillations, derived from the formula

$$i_1 = \frac{c}{f} \sqrt{d},$$

in which i_1 is the effective value of the harmonic in question, f the frequency, d the hot-wire deflection, and c a constant. The deflections are thus corrected for frequency (§ 20) and for the parabolic form of the hot-wire relation.

§ 27. Perfect agreement between the different harmonics in each group cannot be expected, as indeed other observers have found that not all the harmonic frequencies in electrical oscillations are integral multiples of the fundamental. Moreover in the present case it is not impossible that some one portion of the circuit, whose natural period is not far from that of one of the harmonics, may introduce a disturbing element.

§ 28. By using in the resonating circuit a coil of very small self-inductance, frequencies have been observed as high as nine million. This must be a harmonic of the order of the thirty-sixth, unless it is due simply to a small portion of the discharge circuit in which feeble oscillations of very high frequency were excited.

§ 29. *Are the oscillations undamped?*—A satisfactory answer to this question cannot be obtained from most of the resonance curves. Some of the curves examined, including that in fig. 2, gave as the sum of the decrements in the primary and secondary circuits values ranging as high as 0·124. As the secondary decrement could be computed from the constants of the condenser circuit, the apparent decrement of the primary oscillations was found by subtraction. This gave, in the case of the curves referred to, primary decrements of from 0·07 to 0·10.

But on other occasions, when the discharge consented to take place steadily for a sufficiently long time, sharply-pointed resonance curves were obtained, showing a primary decrement no larger than 0·005.

It looks as if the glow-arc oscillations were of themselves undamped, the flatness of the curves being caused by the continually fluctuating frequency and intensity. If, on the other hand, the discharge were a succession of true sparks, one would expect the damping to be greater and the higher harmonics less pronounced.

There is much similarity between the production of these oscillations and those studied by M. Wien for the generation of undamped oscillations by "Stosserregung."* The essential differences are made clear in §§ 9, 10, 13, and 14. Moreover, in Wien's method the damping of the secondary circuit must be small in comparison with that of the primary. Although we do not know the resistance of the discharge-gap to the oscillations described in this paper, still the evidence of the resonance curves points to a larger damping in the secondary than in the primary circuit.

§ 30. *Quantity of matter liberated from the cathode per oscillation.*—During oscillations, the anode is not perceptibly attacked. The cathode wastes away so slowly that it seemed worth while to ascertain how small a fraction of a gram is volatilized each time the discharge is on the arc phase. The oscillations were accordingly allowed to pass as continuously as possible for one hour, the current being 0·12 amp., funda-

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* M. Wien, Ann. Phys., xxv, p. 625, 1908.

mental frequency about 240,000. The loss in mass of the copper cathode was 0·018 gram. corresponding to a loss per period of $2·1 \times 10^{-11}$ gram. This is the mass of about $3·5 \times 10^{11}$ atoms of copper.

§ 31. *Oscillating system in parallel with the discharge.*—It seemed of interest to try the effect on the discharge of connecting in parallel with it a capacity and self-inductance. I have not been able to obtain anything except oscillations of the Duddell type under these conditions, in fact the glow-arc oscillations seemed much diminished in intensity, while the direct current of the supply increased on closing the condenser circuit. The discharge became steadier and more like a stable arc in appearance.

§ 32. *Radiation of energy from the discharge circuit.*—With a discharge between copper terminals in air, giving oscillations feeble and of low frequency in comparison with those later used, an ordinary telephone receiver emitted a rustling sound when held more than a meter distant from the discharge. The receiver was connected between two straight wires, each 60^{cm} long, terminating in tin sheets 10^{cm} square, which served as a detecting system.

From the same discharge, radiations were transmitted to a bolometer four meters distant. They were greatly strengthened by placing a large concave mirror behind the discharge.

Using the stronger oscillations of our later experiments, the bolometer was found to respond when 35 meters away from the discharge circuit. The discharge current itself was carried vertically up the outside of the laboratory for a distance of twelve meters, the circuit being completed inside the building. The energy radiated from this "aerial" was received by a second aerial nine meters high at a neighboring house, and the bolometer was connected between this and the ground.

SUMMARY.

1. The apparatus is described for producing glow-arc oscillations of high frequency. Either alternating or direct e.m.f. may be used.

2. A number of experiments are described, using incandescent lamps or hot-wire ammeters, demonstrating some of the effects of these high-frequency currents and their upper harmonics.

3. Under favorable circumstances 66 per cent of the energy supplied to the discharge can be converted into oscillating currents.

4. The frequency of the fundamental wave observed in most cases was of the order of a quarter of a million.

5. The effects of varying the capacity, self-inductance, and current of the discharge circuit are described.

6. By means of a tuned resonating circuit the presence and relative intensities of a large number of high harmonics were investigated.

7. Observations of damping were carried out with difficulty, but they indicate that the oscillations are undamped.

8. The quantity of matter volatilized at the cathode on the arc phase per cycle was measured.

9. When a capacity and self-inductance are connected in parallel with the discharge, the oscillations are diminished.

10. Experiments are described that illustrate the radiation of electromagnetic waves from the discharge and from the portions of the circuit adjacent to it.

ERRATUM.—In the second paper, page 97, line 32, for "0·3 amp." *read* "3 amp."

Scott Laboratory of Physics,
Wesleyan University, June 11, 1909.

Art. XXVI.—*The Initial Velocities of the Electrons Produced by Ultra-Violet Light*; by Albert W. Hull.

[Contributions from the Sloane Physical Laboratory of Yale College.]

Lenard* was the first to investigate the initial velocities with which electrons are shot out by a metal plate illuminated by ultra-violet light. He found that the velocities varied with the nature of the illuminated metal and the source of light, but were independent of the intensity of the light, from which he concluded that the effect must be due to resonance, but that the greater part of the energy of the electrons must come from within the atom, "the resonance playing only a releasing role." Ladenburg† investigated more carefully the nature of this resonance effect, and found that, for a given metal, the maximum velocity of the electrons emitted was directly proportional to the frequency of the incident light. More recently Ladenburg and Markau‡ have shown that, for a particular spectral region, all the electrons liberated have velocities lying between narrow limits, and they conclude that each wave-length liberates electrons whose frequency of vibration has a definite relation to that of the light, and whose initial velocities are, therefore, either all equal or grouped closely about a mean.

The range of wave-lengths used by these investigators was from λ 2000 to λ 2700. The importance of the results makes it desirable that they be verified for a wider range. The present paper contains an account of experiments on this subject in the region of short wave-lengths discovered by Schumann.

The general method is the same as that used by Lenard and by Ladenburg and Markau. The source of light was an internal capillary discharge tube of the type used by Lyman§ in his spectroscopic work, filled to about one millimeter pressure with hydrogen or carbon dioxide, and closed by a fluorite plate. Different wave-lengths were obtained by interposing various absorbing screens between the discharge tube and the photo-electric chamber.

Before describing the final experiments, a word should be said about some attempts which were unsuccessful. Using the method of auxiliary field employed by Ladenburg and Markau for preventing reflection of electrons, with an apparatus exactly similar to that shown in figure 4 of their paper,‖ the

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* P. Lenard, Ann. Physik., ii, p. 359, 1900; viii, p. 149, 1902.

† E. Ladenburg, Phys. Zeitschr., viii, p. 590, 1907.

‡ Ladenburg and Markau, ibid., ix, p. 821, 1908.

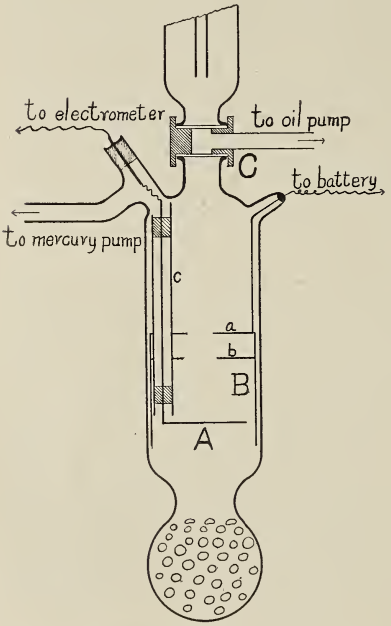
§ T. Lyman, Astrophys. J., xxiii, p. 189, 1906.

‖ Ladenburg and Markau, loc. cit.

author was unable to get results comparable with theirs. The current of electrons increased continually and rapidly with the potential difference between the illuminated plate and gauze, until the latter reached about 40 volts. From this point on the current remained practically saturated, showing that the lack of saturation at lower potentials was not due to an insufficient vacuum. It might be explained by the assumption that the photo-electric radiation of electrons, even from a polished plate, is diffuse, as Lenard showed it to be from a plate covered with lampblack. But this assumption would not explain the saturation observed by Ladenburg and Markau.

The method finally adopted was the following: Light from an internal capillary discharge tube passes through a screen cell C (fig. 1) 1^{cm} in length, closed by fluorite windows, through the limiting diaphragms *a* and *b*, and falls on the insulated electrode A. A is supported by a stem which passes through amber plugs in the brass tube *c*, is sealed into the glass tube by amber and sealing wax, and connected to a Dolezalek electrometer. The diaphragms *a* and *b* are connected to the brass cylinder B, which is insulated and can be charged to known potentials. All parts of B and A are covered with lampblack from an acetylene flame. In the lower end of the glass tube containing the electrodes is 10 grams of cocoanut charcoal, which is heated while the tube is being exhausted, so that after cooling the pressure is $\cdot 001^{\mathrm{mm}}$. The tube is then sealed off from the pump, and immersed in liquid air above the level of the cylinder B. Diffusion of gas out of the lampblack on the electrodes is thus prevented, and a high vacuum assured.

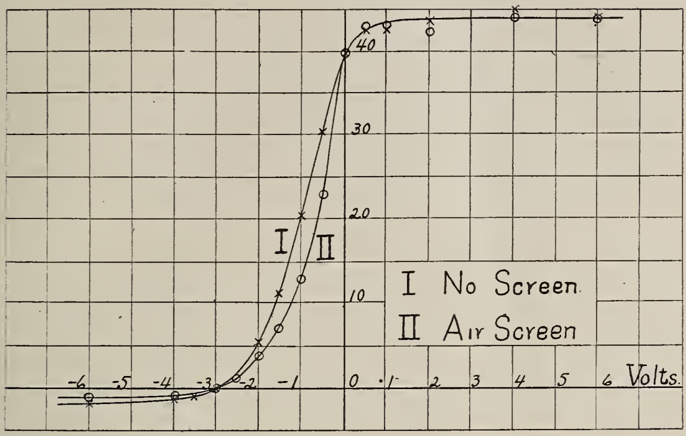
Fig. 1.



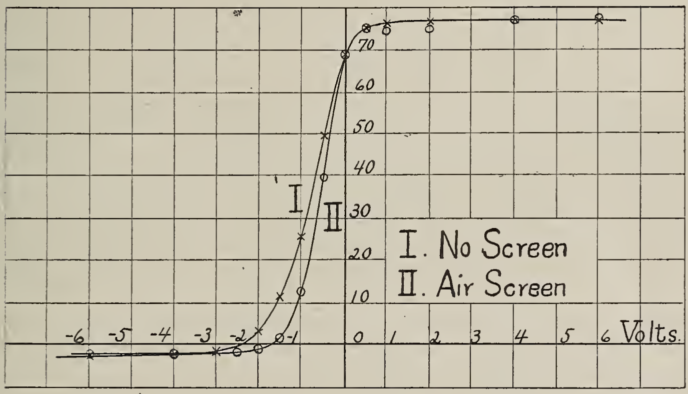
To determine the initial velocities of the electrons, B is charged to small negative potentials, and the current between A and B measured by the electrometer. Only those electrons whose initial kinetic energy, divided by their charge, exceeds the potential difference between A and B will be able to escape

Figs. 2, 3, 4.

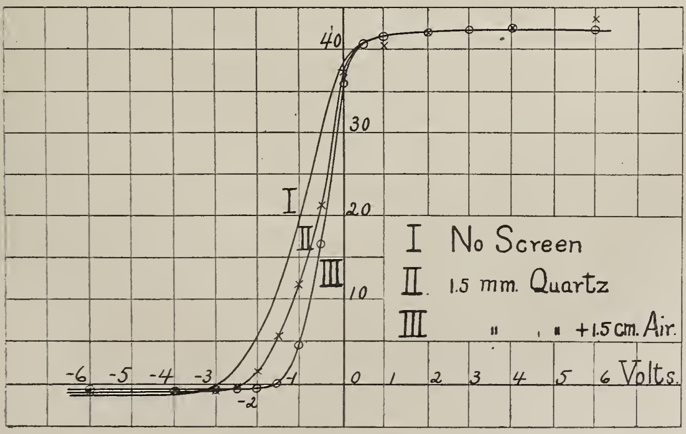
2.



3.



4.



Abscissas represent potential difference between A and B; ordinates the quantity of neg. electricity escaping from A per min. The ordinates of the curves II in figs. 2 and 3, and curves III in fig. 4, are magnified so that their maxima coincide with curve I.

from A. Hence the electrometer deflections will be proportional to the number of electrons whose energy per unit charge* exceeds the corresponding potential of B. The *maximum* energy possessed by any of the electrons will be that potential which is just sufficient to prevent any of them from escaping, and is given by the point where the curves in figures 2, 3 and 4 become tangent to the straight line representing the constant negative leak due to reflected light. From the values of the energy the velocity can at once be determined by substituting the known value of $\frac{e}{m}$.

The experiment was first tried with hydrogen in the discharge tube. When the screen cell C is exhausted, the hydrogen discharge throws upon A light of all wave-lengths down to λ 1230, the limit of transparency of white fluorite.† Filling the cell with air at atmospheric pressure cuts off practically everything below λ 1710.‡ In this way two definite spectral regions are obtained, and since the effect without air in the screen cell is 25 times as great as with it,—that is, the electrons produced by the hydrogen light of longer wave-length than λ1710 are only 4 per cent. of the total, this region of shorter wave-lengths may be taken to extend from λ 1230 to λ 1710.

The results are given in Table I and figure 2. The ordinates of curve II are magnified so that their maximum, representing the total number of electrons set free by the light, coincides with that of curve I. While the two curves show a somewhat different distribution of velocities, indicating a larger proportion of high velocity electrons for the light of higher frequency, the maximum velocity is the same for both. It appeared from this that the proportionality, discovered by Ladenburg, between the velocity of the electrons and the frequency of the light producing them, did not extend to these short wave-lengths. For the shortest wave-length in the unscreened light was estimated to be λ 1230, that in the screened light λ 1710, so that the maximum velocities should have been very different in the two cases.

As a variation of the experiment the discharge tube was filled with carbon dioxide, and now a different result was obtained. There was a very marked difference in the maxima, as is shown in the second part of Table I and figure 3. Without the air screen the maximum energy of the electrons is about 3·3 volts, with the screen only 2·5 volts. If the shortest wave-length in the spectrum of carbon dioxide is taken as

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* For the sake of brevity, the energy per unit charge will hereafter be designated simply as energy of the electrons.

† See T. Lyman, Astrophys. J., xxv, p. 45, 1907.

‡ See T. Lyman, ibid., xxvii, p. 87, 1908.

Table I.

Loss of Neg. Electricity by A.

Coulombs per min. $\times 10^{-8}$

	H_2 Light		CO_2 Light	
Pot. of B volts	Without air screen	With air screen	Without air screen	With air screen
−6	−2	−0·072	−0·27	−0·065
−4	−1·5	−0·059	−0·23	----
−3·5	−1·25	----	----	----
−3·0	−0·05	0·002	−0·17	----
−2·5	2·0	0·077	−0·08	−0·063
−2·0	5·7	0·185	0·38	−0·041
−1·5	11·2	0·340	1·12	0·039
−1·0	20·8	0·640	2·59	0·367
−0·5	30·5	1·14	4·95	1·18
0·	39·8	1·99	7·00	2·09
+0·5	42·5	2·15	7·53	2·26
+1	42·5	2·15	7·62	2·22
+2	43·6	2·12	7·67	2·23
+4	45·0	2·20	7·66	2·31
+6	44·0	2·18	7·63	2·33

about 1480, and the limit of the absorption of air as λ 1107, then the inverse of these wave-lengths are proportional to the maximum velocities, that is, to the square-roots of the maximum energy given above, which fits Ladenburg's hypothesis.

This suggested that the results with hydrogen light might be explained by a small amount of light of very short wavelength getting through the air in the screen-cell. Lyman * has shown that the absorption of air is in the form of a band, which, for a column of air 0·91$^{\mathrm{cm}}$ long at atmospheric pressure, extends from about λ 1710 to λ 1270. The more refrangible limit of the band is so indistinct on a photographic plate that Schumann was unable to detect it at all.† But the photo-electric effect is probably more sensitive than a photographic plate, especially for the shortest wave-lengths, since, as Ladenburg has shown, it increases very rapidly with decrease in wave-length. Moreover the ordinates of curve II in figure 2 are magnified twenty-five times. Hence a very small amount of light between λ 1270 and λ 1230 might produce enough high-velocity electrons to change the form of the lower part of curve II, and since the shortest wave-length, λ 1230, is the same as without the air screen (curve I), the maximum velocity would be the same for both.

To test this point the discharge tube was disconnected from the fluorite cover of the screen cell C, and closed by a separate

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* T. Lyman, Astrophys. J., xxvii, p. 103, 1908.

† Schumann, Smithsonian Contributions, No. 1413.

fluorite plate. It was then adjusted in a vertical position so that it could be raised enough for a quartz plate, 1·5^{mm} thick, to be placed between it and the cell C. Lyman* has shown that quartz of this thickness absorbs all light below λ 1450.

The results with the quartz are given in Table II and figure 4. The absolute values cannot be compared with those in Table I, since the intensity of the light was not the same. The scale of ordinates of the different curves in this, as in the previous figures, is so chosen that their maxima coincide. Curve I, which gives the velocities without the quartz and with the cell C evacuated, is the same as curve I in figure 2, and is inserted here for comparison. It shows a maximum energy of about 3·5 volts, produced by light of λ 1230. Curve II, obtained with the quartz, but no air in the screen cell, gives a maximum energy of about 3 volts, which must be due to light of λ 1450–1500, the limit of transparency of quartz.† Curve III shows the effect of both quartz and air screen. It represents the same conditions as curve II in figure 2, except that the small amount of light between λ 1270 and λ 1230 has now been cut out by the quartz. The maximum energy is now about 2·4 volts, which must be due to light of λ 1710, the less refrangible limit of the air absorption band.

TABLE II.

H_2 Light

Loss of Neg. Electricity by A.
Coulombs per min. × 10^{-9}

Pot. of B volts	1·5^{mm} Quartz screen	1·5^{mm} Quartz + 1·5^{cm} air
−6	−0·88	−0·034
−4	−0·79	−0·036
−3	−0·78	−0·031
−2·5	−0·285	−0·030
−2·0	1·52	−0·029
−1·5	5·55	0·009
−1·0	12·3	0·223
−0·5	21·5	0·845
0	37·4	1·86
+0·5	- - - -	2·11
+1·0	40·3	2·14
+2·0	42·1	2·17
+3·0	- - - -	2·18
+4·0	42·5	2·20
+6·0	43·8	2·17

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* T. Lyman, Astrophys. J., xxv, p. 49, 1907.

† Lyman's photographs show that the absorption of 2^{mm} of quartz is complete below about λ 1500, that of 0·2^{mm} below λ 1450. The limit for 1·5^{mm} will be between these values.

The exact values of the maximum energy are hard to determine, but the points of zero deflection of the electrometer, where the curves cut the axis of abscissas, can easily be determined to within 0·01 volt, and since it is probable that the same *proportion* of light is reflected in each experiment, the potentials represented by these points will be nearly proportional to the real maxima. These values will therefore be used in testing the proportionality between light-frequency and the velocity of the electrons, and are designated in Table III as maximum energy.

If the results of Ladenburg hold for this region, the maximum energies and the *shortest* wave-lengths in the light producing them should be related according to the equation $\frac{1}{\lambda_1} : \frac{1}{\lambda_2} = \sqrt{V_1} : \sqrt{V_2}$, where V is the energy in volts. If we take as a fixed point of reference the shortest wave-length in the hydrogen spectrum which can get through white fluorite, λ 1230 as determined by Lyman, to which corresponds the maximum energy, 3·03 volts, the other wave-lengths can then be calculated by the formula

$$\lambda = 1230 \sqrt{\frac{3{\cdot}03}{V}}$$

and the calculated values compared with those which are known from spectroscopic experiments. This has been done in Table III.

TABLE III.

Source of Light	Screen	Maximum Energy in volts	Shortest Wave-length — Calculated on Ladenburg's Theory	Shortest Wave-length — Estimated from Spectroscopic Experiments
H_2 - - -	2^{mm} fluorite	3·03	[1230]	1230
CO_2 - -	2^{mm} fluorite	2·42	1375	above 1230
H_2 - - -	$1{\cdot}5^{mm}$ quartz	2 33	1400	1450–1500
H_2 - - -	$1{\cdot}5^{mm}$ quartz + $1{\cdot}5^{cm}$ air	1·58	1710	1710
CO_2 - -	$1{\cdot}5^{cm}$ air	1·62	1680	1710 (or a little less)

In regard to the values of λ in the last column, those for hydrogen, taken from Lyman's results with the vacuum spectrograph, may be regarded as well fixed, although some of them may be too high for the photo-electric effect, which is probably more sensitive than a photographic plate, especially in the region of very short wave-lengths. This may account for the low value obtained with quartz.

In the case of carbon dioxide, all that I have been able to find about the emission spectrum in this region is the following statement by Schumann:[*] "Its photographic action is uncommonly strong, and it extends far beyond $162\mu\mu$ into the region of the shortest wave-lengths. I doubt not that, were the tubes sufficiently transparent, it could be photographed as far as the hydrogen spectrum extends. For its wealth of lines it stands unrivalled." From this statement it appears that, whatever the cause, the spectrum of carbon dioxide photographed by Schumann did not extend quite as far as the hydrogen spectrum. The value λ 1375 is, therefore, a very reasonable one.

The less refrangible limit of the air absorption band should be about the same for carbon dioxide as for air, except that it might be a little lower for carbon dioxide, owing to its "wealth of lines" in this region.[†] The results seem to indicate that this is the case.

The agreement is, therefore, as good as our present knowledge of absorption in this region will warrant. For the two cases where this knowledge is most accurate, namely the limit of the hydrogen spectrum due to the absorption of white fluorite, and the less refrangible limit of the air absorption band, the agreement is remarkably good.[‡] An exact comparison of these results with those obtained by Ladenburg for longer wave-lengths is impossible, owing to the difference in method and in the nature of the illuminated metal. In Ladenburg's apparatus there was very little light reflected to the receiving wires (corresponding to our electrode B). Hence his maximum velocities correspond more nearly to the real maxima defined above than to the relative maxima of Table III. The metals investigated by Ladenburg were platinum, copper, and zinc, and for λ 2010, his shortest wave-length, he found as maximum energy: for platinum, 1·86 volts; for copper, 1·69 volts; for zinc, 1·12 volts; and he observed that the energy was greater the more electro-negative the metal was. If this order holds in general, the maximum energy for carbon for λ 2010 should be between 1·86 and 1·69 volts, and for λ 1710, extrapolating on Ladenburg's hypothesis, it would be between 2·57 and 2·33 volts. The value of about 2·5 volts found above for λ 1710 lies between these limits. The agreement is, therefore, *qualitatively* correct.

The question of velocities between zero and the maximum requires further investigation. The fact that a positive poten-

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[*] V. Schumann, Smithsonian Contributions, No. 1413, p. 16.

[†] Hydrogen gives only a weak continuous spectrum between λ 1675 and λ 3700. Lyman, Astrophys. J., xxiii, p. 199, 1906; Schumann, l. c. p. 28.

[‡] The exact agreement is of course accidental.

tial of about one volt on B is required to enable all the electrons produced on A to escape is probably due to two causes.

(1) Reflection of the electrons from B. O. v. Baeyer* has shown that even a lampblack surface reflects diffusely about ten per cent of the electrons which strike it. The better saturation obtained by Ladenburg and Markau may be explained by the fact that their apparatus had a blackened wire gauze in front of the lampblacked surface corresponding to B, which still further lessened the reflection.

(2) Entanglement of the diffusely radiated electrons by the rough surface of the blackened radiator A. If a blackened surface so entangles the electrons which strike it as to prevent, in a large measure, their reflection, it is probable that it also hinders, to some extent, their escape from the illuminated plate.

The question whether the electrons liberated by light of a particular wave-length are all of one velocity or of several velocities is of great importance to the theory of the photo-electric effect, and the author proposes to extend the work of Ladenburg and Markau on this subject to the region of shorter wave-lengths.

Before concluding, the author wishes to express his thanks to Professor Bumstead, at whose suggestion this investigation was undertaken, for his interest in the work, and to Professor Boltwood for many valuable suggestions.

Summary.

The initial kinetic energy of the electrons liberated from carbon by light between λ 1710 and λ 1230 has been measured, and the proportionality, discovered by Ladenburg, between the maximum initial velocity of the electrons, i. e. the square root of their maximum initial kinetic energy, and the frequency of the light producing them, has been found to hold for these short wave-lengths, to the degree of accuracy with which this part of the spectrum is known. It may now be stated that, for the entire range, λ 2700 to λ 1230, the initial velocities of the fastest electrons liberated by light of particular frequencies are proportional to these frequencies. The question of the production of electrons other than the fastest will be further investigated.

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* O. v. Baeyer, Phys. Zeitschr., x, p. 181, 1909.

Art. XXVII.—*A New Declination Instrument;* by C. C. Hutchins.

The declination is the only magnetic element that the engineer and navigator wish to know, and it is hoped that the apparatus to be here described will be found as useful and much more simple than commonly employed in finding it. Reference to the figure will make the following details plain.

We have a telescope of 1-inch diameter and 6-inch focus. Upon the telescope tube are two carefully turned bronze rings upon which the telescope rests in a light cradle C–D. The cradle is suspended with floss silk from a torsion-head H.

The telescope hangs in a box upon which are mounted two level phials. One side of the box is of glass and is removed by a convenient knob K.

A rod runs the length of the box and bears two hook-like supports A–B. When the rod is revolved by means of a lever at the eyepiece end, and the lever slipped over a catch at O, the supports then lift the telescope from its cradle and support it. The eyepiece of the telescope projects through one end of the box, where it is covered with a cap to protect it from air currents. Before the objective is a plate-glass window.

The whole is mounted upon a small divided circle reading to minutes. The socket of the circle may be made to fit the ordinary engineer's tripod.

The peculiarity of the apparatus lies in the telescope, whose tube is made of steel and is magnetized. It was found that a very satisfactory tube could be made by case-hardening a piece of ordinary bicycle tubing, and magnetizing. The eyepiece of the telescope has a single wire at its focus.

The operation of the instrument is as follows:—

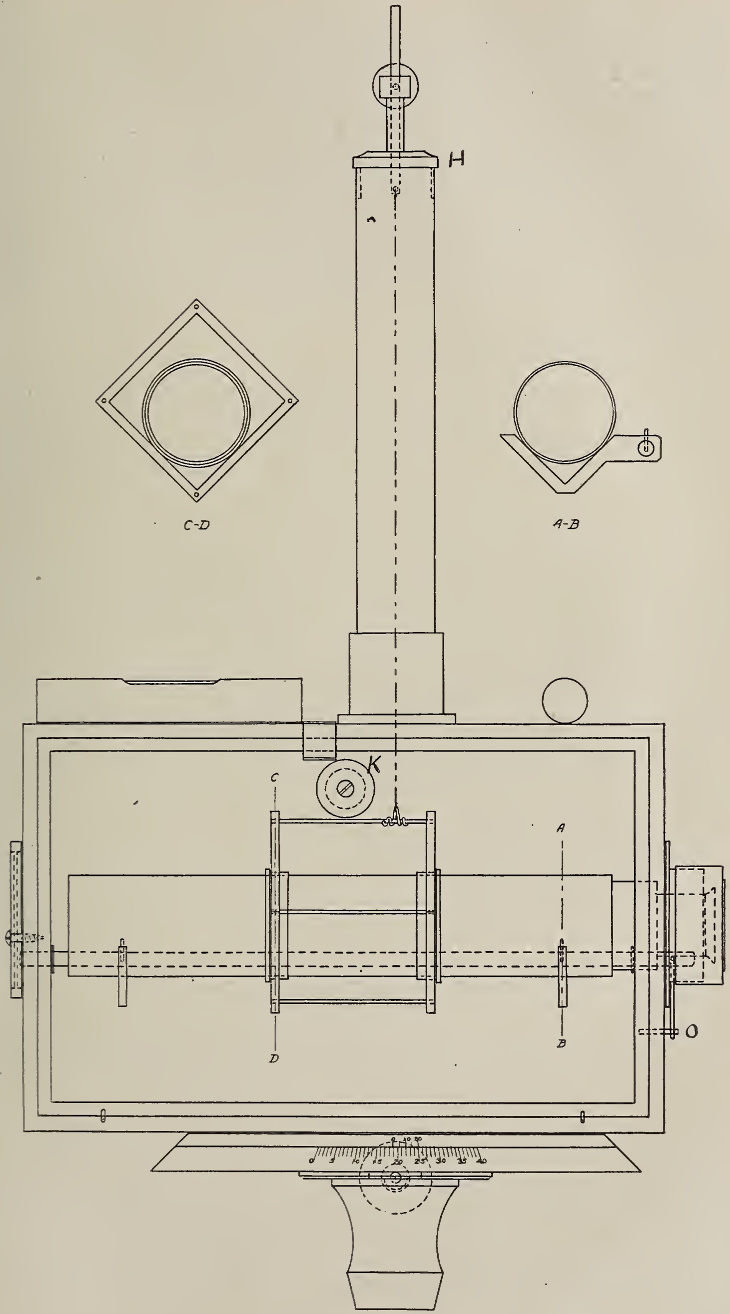
It is set up on a meridian line. About 200 feet away, and in the approximate direction of the magnetic meridian, is placed a horizontal scale divided to inches, with bold marks.

The telescope being removed from the box, a brass tube of the same weight is substituted, and the torsion head is rotated until the suspension is free from torsion. The telescope is replaced and the box being rotated until it points to the distant scale, the excursions of the vertical wire are observed, and its point of rest found in the usual way. This observation is repeated after rotating the telescope 180° in its cradle.

This eliminates the effects of parallax and the lack of coincidence of the magnetic and telescopic axes.

The mean of the two points of rest is found; the telescope

FIG. 1.



lifted from the cradle to the supports A–B and the circle rotated until the eyepiece wire marks the mean point of rest. The circle is now read, and a pointing being made upon the meridian mark, the change in the circle reading is the declination sought. The declination is rarely wanted closer than the nearest minute, in fact considering the rapidity with which it changes is not obtainable to less than that amount, and experience has shown that an apparatus of the above dimensions is needlessly large for that degree of accuracy.

A telescope of four inches length would doubtless do as well, and thereby the whole would become very compact and portable.

Bowdoin College, June 14, 1909.

Art. XXVIII—*The Relation between the Refractive Index and the Density of Some Crystallized Silicates and Their Glasses*; by Esper S. Larsen.

Investigators have long sought to discover a simple relation between the index of refraction of a substance and its density which is independent of the temperature and also valid even when the substance is mixed in solution with other substances. Laplace[*] early derived the relation

$$\frac{n^2 - 1}{d} = \text{constant} \qquad (1)$$

from a consideration of Newton's emission theory of light. This formula did not satisfy later experimental data and in the middle of the last century Gladstone and Dale derived the relation

$$\frac{n - 1}{d} = K, \text{ where } K \text{ is a constant} \qquad (2)$$

which they called the specific refractive energy. Theoretically, this formula is based upon the assumption that the molecules in the line of transmission of a given light wave retard that wave by an amount which is independent of their arrangement and distribution along that wave. Their own statement is:[†] "Every liquid has a specific refractive energy composed of the specific refractive energies of its component elements, modified by the manner of combination, and which is unaffected by change of temperature, and accompanies it when mixed with other liquids. The product of this specific refractive energy and the density is, when added to unity, the refractive index." More recently, Lorentz[‡] and Lorenz[§], on the basis of the electromagnetic theory of light, independently derived the relation:

$$\frac{n^2 - 1}{n^2 + 2} \cdot \frac{1}{d} = K_2 \qquad (3)$$

The specific refractive energy being an additive property, we may immediately write the relation,

$$K_1 = k \frac{p_1}{100} \qquad (4)$$

where K is the specific refractivity of the mixture and k that of any component, while p is the weight per cent of that com-

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[*] Traité de Mécanique Céleste, IV, x, 232.

[†] Phil. Trans., 337, 1863.

[‡] Wied. Ann., ix, 641, 1880.

[§] Ibid., xi, 70, 1880.

ponent present. We can apply this formula to the elements making up a compound as well as to a simple mixture or solution. An identical relation holds for the formula of Lorentz and Lorenz:

$$K_2 = k_2 \frac{p}{100} \qquad (5)$$

Since the appearance of the papers of Gladstone and Dale, much work has been done to test their formula and several other formulæ have been proposed, but only those of Gladstone and Dale and of Lorentz and Lorenz have theoretical significance or general application. Both formulæ, together with the corresponding formulæ for dispersion and for the additive relation for solutions and the elements of a compound, have been carefully tested on many organic liquids and salt solutions. In general, the two formulæ hold almost equally well for varying temperatures and concentrations, the first holding better in one case and the second in another. Lorenz,[*] Bruhle,[†] and others have shown that when applied to a substance in different states,—to a gas and a liquid, for example—the simpler formula gives errors as great as thirty per cent, while the n^2 formula gives lower though still considerable errors. Landolt,[‡] Conrady,[§] and other investigators showed that in organic liquids the refractive constant depends upon the atomic constitution as well as upon the chemical composition, and that some elements, such as oxygen, must be given different values for k, depending upon the structure of the molecule.

An excellent monograph, including a review of former work on this subject and a complete bibliography, has recently been published by Cheneveau.[‖]

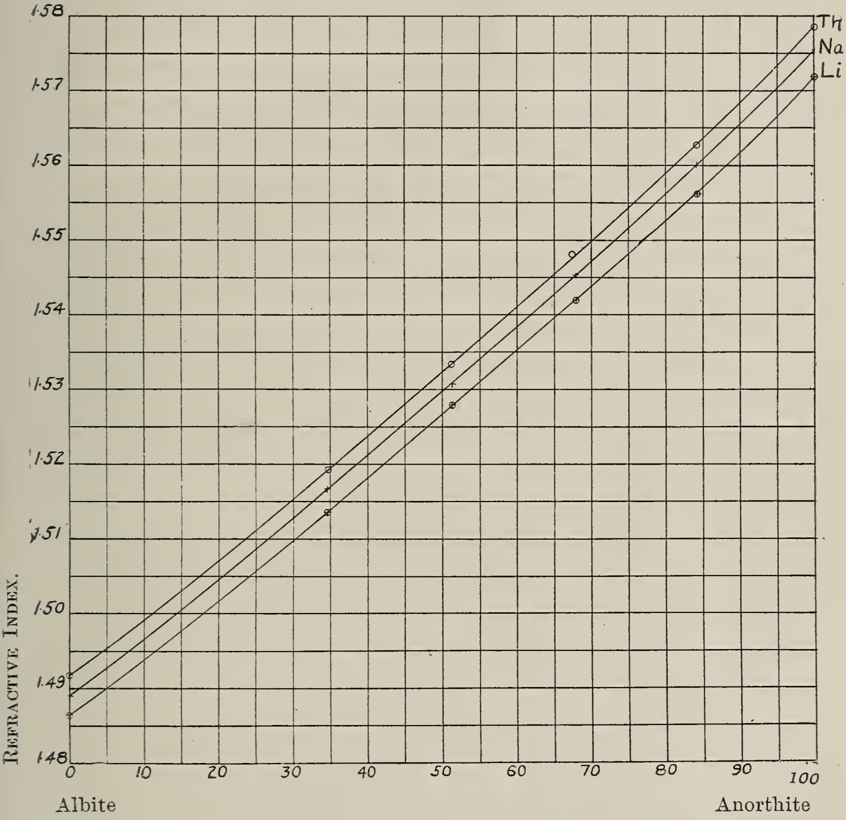
At the present time, but few data are available for the application of these formulæ to silicate glasses and to minerals of simple, known composition. The present investigation was undertaken to secure such data and to test the application of the formulæ to several different silicate glasses and corresponding minerals. The two series selected for study were the soda-lime feldspar series and the three component system $CaO{-}MgO{-}SiO_2$, with especial emphasis on the metasilicates.

The glasses were prepared by mixing the pure components and melting, then grinding and remelting several times to secure homogeneity. The probable error in composition should not exceed 0·3 per cent.[¶] Glasses rich in CaO and MgO could not be prepared on account of their strong tendency to crystallize. The crystals were prepared in the course of the

[*] Wied. Ann., xi, 70, 1880.
[†] Zeitschr. f. phys. Chem., vii, 1, 1891.
[‡] Pogg. Ann., cxvii, 353, 1862.
[§] Zeitschr. f. phys. Chem., iii, 210, 1889.
[‖] Ann. d. Chém. et Phys., xii, 145, 289, 1907.
[¶] Allen, E. T., and W. P. White, this Journal (4), xxvii, 2, 1909.

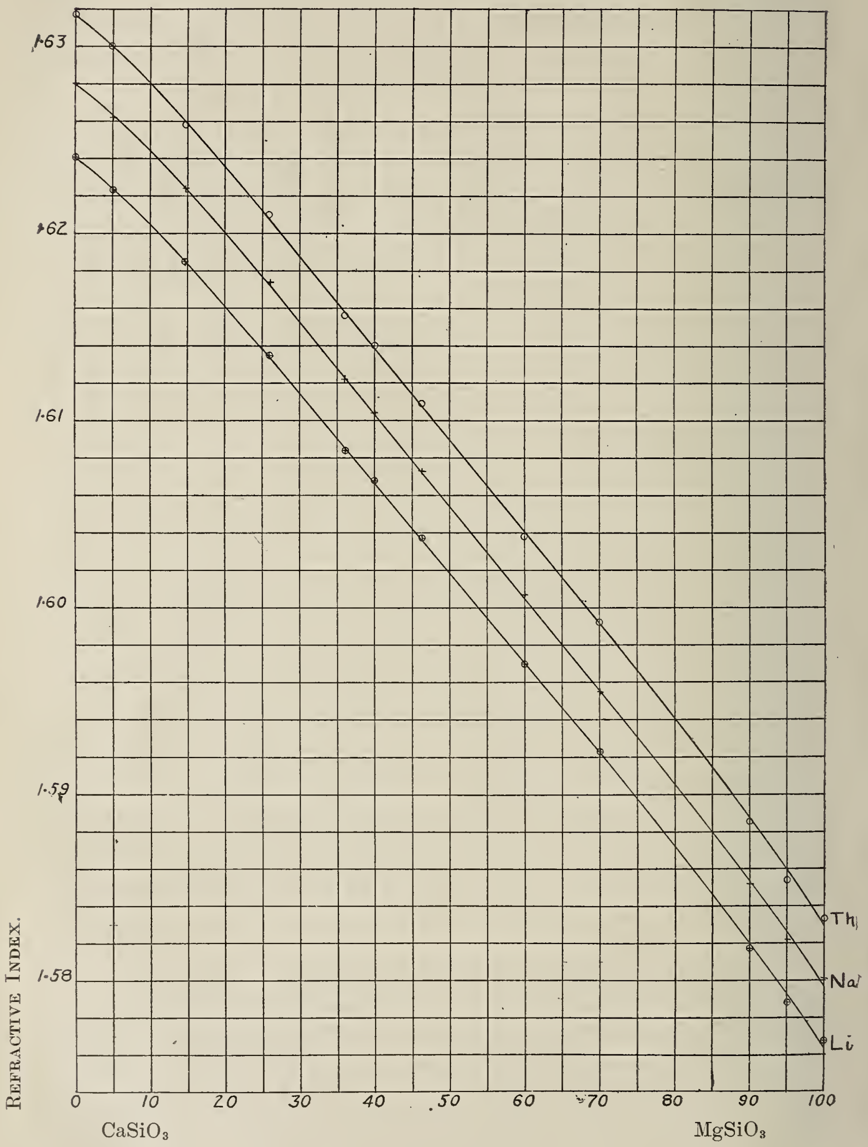
synthetic work of the Geophysical Laboratory and the method of preparation and purity are discussed in publications to which explicit reference will be made further on.

FIG. 1.



The indices of refraction of the glasses were determined by the method of minimum deviation and each was checked by two separate wedges. The measurements were made on a Goldschmidt two-circle goniometer, using lithium, sodium and thallium lights, and the angles checked to the nearest minute. The measurements for the two wedges usually checked to within 0·0004 and the probable error is ±0·0003. The results for the measurements of the feldspar glasses are given in Table 1, and are plotted in fig. 1; those for the metasilicates of calcium and magnesium in Table 2 and fig. 2; and those of the other silicates of calcium and magnesium in Table 3.

FIG. 2.



As shown in the columns headed $N_{Th}-N_{Li}$ the dispersion varies continuously, within the limits of error, between the end members in both series. The next column, headed

$\frac{N-N'}{N}.100$, gives the percentage which the index of refraction for any intermediate member exceeds the value computed on the assumption that it is an additive function of the end members. In the (Ca,Mg)SiO_3 series this excess is positive and is well beyond the limits of error. The plot of figure 2 shows a curve which is sensibly straight throughout its central part but which bends down rather sharply at both ends. The data for the feldspar glass show a negative deviation as indicated by the curves plotted in figure 1. These are also sensibly straight throughout their central portion, but bend up at both ends.[*]

The specific gravities of the glasses were determined on powder of 100 mesh size in a pycnometer, with water or zylene at 25° C.[†] Separate determinations on material from the same melt usually checked to 0·002, but the difference is somewhat greater when the powders are from different melts. The values for the specific gravities are given in Tables 1, 2 and 3 in the columns headed D and are plotted in figs. 3 and 4. The values for the feldspar glasses were taken from the data of Day and Allen.[‡] In the column headed $\frac{V-V'}{V}.100$ is given the percentage of deviation of the specific volume from the

TABLE I.

	Per cent Albite	Per cent Anorthite	N_{Li}	N_{Na}	N_{Th}	$N_{Th}-N_{Li}$	$\frac{N-N'}{N}100$	D	$\frac{1}{D}=V$	$\frac{V-V'}{V}100$
Ab	100·00	0·00	1·4864 1·4865	1·4891 1·4889	1·4916 1·4917	·0052 ·0052	0·00	2·382	·4198	0·00
Ab_2An_1 ..	65·37	34·63	1·5136 1·5134	1·5168 1·5164	1·5194 1·5191	·0058 ·0057	−0·16	2·483	·4027	+0·02
Ab_1An_1 ..	48·55	51·45	1·5281 1·5276	1·5309 1·5306	1·5335− 1·5334	·0054 ·0058	−0·18	2·533	·3948	+0·11
Ab_1An_2 ..	32·05	67·95	1·5420+ 1·5420	1·5451− 1·5453	1·5480 1·5482−	·0060 ·0062	−0·16	2·591	·3859	−0·07
Ab_1An_5 .	15·87	84·13	1·5562 1·5565	1·5600 1·5600	1·5628 1·5629−	·0066 ·0064	−0·12	2·648	·3776	−0·15
An	0·00	100·00	1·5720 1·5718	1·5756 1·5754	1·5786 1·5786	·0066 ·0068	0·00	2·700	·3704	0·00

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[*] For data on similar deviations for isomorphous artificial crystals, see Fock, Zeitschr. f. Kryst., iv, 583, 1880.

[†] Isomorphism and thermal properties of the feldspars, Pub. No. 31, Carnegie Institution of Washington, p. 55.

[‡] Loc. cit.

TABLE II.

Per cent $CaSiO_3$	$MgSiO_3$	N_{Li}	N_{Na}	N_{Th}	$N_{Th}-N_{Li}$	$\frac{N-N'}{N'}.100$	D	$\frac{1}{D}=V$	$\frac{V-V'}{V'}.100$
100·00	0·00	1·6242+ 1·6240+	1·6281– 1·6280	1·6317 1·6317	·0075 ·0077	0·00	2·904 2·904	·3444	0·00
95·00	5·00	1·6224+ 1·6221	1·6263+ 1·6260+	1·6300 1·6299	·0076 ·0078	+0·04	2·899	·3450	–0·09
85·26	14·74	1·6183 1·6187	1·6222 1·6225	1·6256 1·6260	·0073 ·0073	+0·09	2·892 2·891	·3458	–0·34
74·00	26·00	1·6135 1·6136	1·6175 1·6174	1·6210 1·6210	·0075 ·0074	+0·13	2·882 2·880	·3471	–0·57
64·00	36·00	1·6084 1·6084+	1·6122– 1·6122+	1·6155+ 1·6156+	·0071 ·0072	+0·09	2·872 2·873 2·870	·3482	–0·80
60·00	40·00	1·6068 1·6067	1·6106 1·6104	1·6140 1·6139	·0072 ·0072	+0·11	2·858	·3499	–0·51
53·64	46·36	1·6038 1·6035	1·6074 1·6072	1·6111 1·6107	·0073 ·0072	+0·10	2·854 2·854	·3504	–0·71
40·00	60·00	1·5970 1·5971	1·6006– 1·6008+	1·6035+ 1·6040	·0065 ·0069	+0·09	2·835 2·834	·3528	–0·73
30·00	70·00	1·5926– 1·5921	1·5963+ 1·5957	1·5994 1·5990	·0068 ·0069	+0·09	2·819 2·823 2·820	·3545	–0·76
10·00*	90·00*	1·5819 1·5818	1·5856– 1·5854	1·5887 1·5887	·0068 ·0069	+0·03	2·881 2·877 2·879	·3599	–0·28
		1·5816 1·5814	1·5851 1·5850	1·5883 1·5880	·0067 ·0066		2·880 2·879		
5·00	95·00	1·5787+ 1·5789	1·5820+ 1·5823	1·5854 1·5854	·0067 ·0065	–0·01	2·777 2·777	·3601	–0·45
0·00	100·00	1·5768 1·5766	1·5802 1·5800	1·5835 1·5831	·0067 ·0065	0·00	2·758 2·757	·3627	0·00

* These two determinations were made on glasses from separate melts.

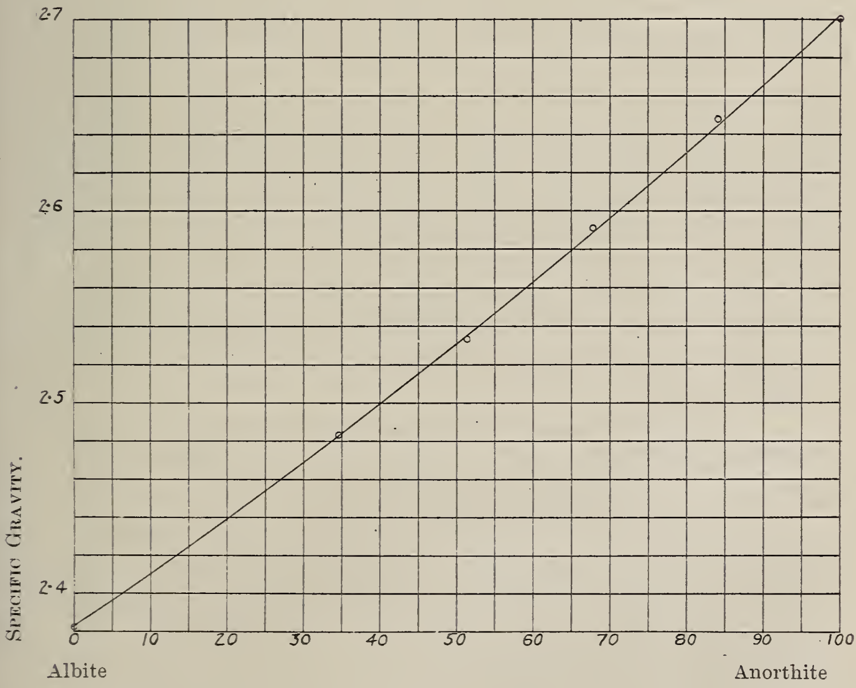
additive value. For the (Ca,Mg)SiO_3 series the values are negative and show clearly a contraction on mixing. The data for the feldspar glasses are not consistent.

The data for the refractive index and density of the various crystalline forms were taken from measurements made in the Geophysical Laboratory on pure artificial material. The probable error of the index of refraction is about ± 0·002, while that for the density is about ± 0·005. The indices of refraction of quartz and of the feldspars are those of the natural minerals.

TABLE III.

Per cent SiO_2	Per cent CaO	Per cent MgO	N_{Li}	N_{Na}	N_{Th}	$N_{Th}-N_{Li}$	D
100·00	0·00	0·00	1·4567 1·4565	1·4589 1·4592	1·4612 1·4612	·0045 ·0047	2·213
46·50	50·00	3·50	1·6365 1·6375	1·6405 1·6416	1·6446 1·6453	·0081 ·0078	2·954 2·952
45·00	40·00	15·00	1·6349 1·6352	1·6391 1·6393	1·6427 1·6430	·0078 ·0078	2·966 2·969
50·20	24·80	25·00	1·6182 1·6185	1·6224 1·6226	1·6262 1·6259	·0080 ·0074	2·920 2·921

FIG. 3.



In birefracting minerals the mean index of refraction was taken

$$n = \frac{2\omega+\epsilon}{3} \text{ or } n = \frac{\alpha+\beta+\gamma}{3}$$

The specific refractivity of the various glasses and crystals studied have been computed according to both the formula of Gladstone and Dale and that of Lorentz and Lorenz, and the results are tabulated in Tables 4, 5 and 6. Table 4 gives the data for the feldspar series. The third column gives the value

TABLE IV.

	N_{Na}	D	$\frac{N-1}{D}=K_1$.	K'_1	$\frac{K_1-K'_1}{K_1}.100$	$\frac{K_1-K''_1}{K_1}.100$	$\frac{N^2-1}{N^2+2}\cdot\frac{1}{D}=K$	K'_2	$\frac{K_2-K'_2}{K_2}.100$	$\frac{K_2-K''_2}{K_2}.100$
Glass										
Ab	1·4890+	2·382	·2053	·2053	0·00		·12117	·12117	0·00	
Ab_2An_1 ...	1·5166	2·483	·2081—	·2080—	+0·05		·12176	·12161	+0·12	
Ab_1An_1 ...	1·5307+	2·533	·2095	·2094	+0·05		·12208	·12185	+0·19	
Ab_1An_2 ...	1·5452	2·591	·2104	·2105	—0·05		·12206	·12206	0·00	
Ab_1An_5 ...	1·5600	2·648	·2115	·2119	—0·19		·12211	·12228	—0·14	
An	1·5755	2·700	·2132—	·2132—	0·00		·12248	·12248	0·00	
Feldspar										
Ab	1·534	2·605	·2050	·2050	0·00	+0·15	·11933	·11933	0·00	+1·52
Ab_2An_1 ...	1·549	2·660	·2064	.2075	—0·55	+0·82	·11958	·12010	—0·43	+1·82
Ab_1An_1 ...	1·558	2·679	·2083	·2088	—0·25	+0·58	·12034	·12047	—0·11	+1·45
Ab_1An_2 ...	1·568	2·710	·2096	·2100	—0·20	+0·38	·12073	12083	—0·08	+1·10
Ab_1An_5 ...	1·577	2·733	·2111	·2112	—0·05	+0·19	·12125	·12119	+0·05	+0·71
An	1·587	2·765	·2123	·2123	0·00	+0·40	·12154	·12154	0·00	+0·77

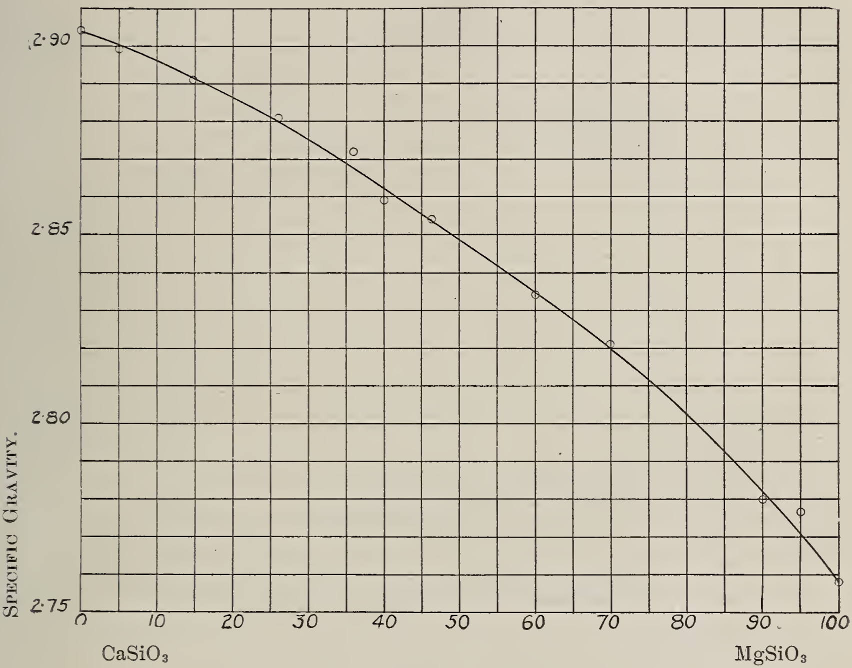
of K_1 as computed from the simpler formula, the next column the value of K'_1 from the end members of the series, on the assumption that it is an additive function. The column headed $\frac{K_1-K'_1}{K_1}.100$ gives the percentage by which K_1 differs from the computed additive value. This difference is within the limits of error for the glasses but is a little greater than the probable error for the feldspars.

The column headed $\frac{K_1-K''_1}{K_1}.100$ gives the percentage by which the specific refractivity of a crystal differs from that of a glass of the same composition. For the feldspars and their glasses this difference is always positive and is somewhat greater than the probable error.

In the last four columns of the same table, corresponding values computed from the n^2 formula are given. The deviation from the additive relation is within the limits of error for both the glass and the crystalline series as in the former case, but the percentage of difference between the constant for a glass and that for the feldspar of the same composition is considerably greater for this formula and is well beyond the probable error.

Table 5 gives the corresponding values for the calcium-magnesium metasilicate series. Here also the law of mixtures holds within the limits of error for the glasses, but when the constant for a glass is compared with that of the crystal of the same composition, the percentage of difference is as great as 3·2 per cent if computed from the simple formula, and 5·3 per cent if computed from the n^2 formula. In this series the constant for the glasses is always greater than that for the crystalline material.

FIG. 4.



The results for the CaO–MgO–SiO$_2$ series are listed in Table 6. They accord well with the former results in that both constants are additive for mixtures of the glasses while neither agree when minerals are compared with glasses or with each other. The percentage difference between the value of K$_1$ for a glass and that of K$''_1$ for a crystalline material of the same composition may be either positive or negative, and become as

TABLE V.

	Per cent $CaSiO_3$	Per cent $MgSiO_3$	N_{Na}	D	$\frac{N-1}{D}=K_1$	K'_1	$\frac{K_1-K'_1}{K_1}.100$	$\frac{K_1-K''_1}{K_1}.100$	$\frac{N^2-1}{N^2+2}\cdot\frac{1}{D}=K_2$	K'_2	$\frac{K_2-K'_2}{K_2}.100$	$\frac{K_2-K''_2}{K_2}.100$
Glass	100·00	0·00	1·6280	2·904	·2163	·2163	0·00		·12220	·12220	0·00	
	95·00	5·00	1·6262	2·899	·2160	·2160	0·00		·12214	·12210	+0·03	
	85·26	14·74	1·6223	2·891	·2153	·2153	0·00		·12187	·12191	−0·03	
	74·00	26·00	1·6174	2·881	·2143	·2146	−0·14		·12151	·12169	−0·15	
	64·00	36·00	1·6122	2·872	·2132	·2139	−0·34		·12107	·12150	−0·35	
	60·00	40·00	1·6105	2·859	·2136	·2136	0·00		·12140	·12142	−0·02	
	53·64	46·36	1·6073	2·854	·2128	·2131	−0·14		·12105	·12130	−0·20	
	40·00	60·00	1·6007	2·834	·2119	·2122	−0·14		·12082	·12103	−0·17	
	30·00	70·00	1·5960	2·821	·2113	·2115	−0·10		·12060	·12084	−0·20	
	10·00	90·00	1·5851	2·780	·2105	·2102	+0·14		·12057	·12045	+0·10	
	5·00	95·00	1·5822	2·777	·2097	·2098	+0·05		·12022	·12035	−0·10	
	0·00	100·00	1·5801	2·758	·2103	·2095	+0.38		·12070	·12025	+0·36	
Wollastonite..........	100·00	0·00	1·625*a*	2·914*c*	·2144			+0·89	·12128			+0·75
Pseudo-wollastonite ..	100·00	0·00	1·623*a*	2·912*c*	·2138			+1·16	·12105			+0·94
Diopside	53·64	46·36	1·676*a*	3·275*a*	·2064			+3·00	·11486			+5·11
Kupfferite	0·00	100·00	1·585*b*	2·857*b*	·2048			+2·49	·11730			+2·66
$\beta-MgSiO_3$	0·00	100·00	1·649*a*	3·192*b*	·2033			+3·20	·11413			+5·30
Enstatite	0·00	100·00	1·646*b*	3·175*b*	·2035			+3·09	·11432			+5·15

a. Diopside and its relation to calcium and magnesium metasilicates, this Journal (4), xxvii, 29, 1909. *b.* Minerals of the composition $MgSiO_3$; a case of tetramorphism, ibid. (4), xxii, 385, 1906. *c.* On wollastonite and pseudo-wollastonite, polymorphic forms of calcium metasilicate, ibid. (4), xxi, 89, 1906.

TABLE VI.

	Per cent SiO_2	Per cent CaO	Per cent MgO	N_{Na}	D	$\frac{N-1}{D}=K_1$	K'_1	$\frac{K_1-K'_1}{K_1}.100$	$\frac{K_1-K''_1}{K_1}.100$	$\frac{N^2-1}{N^2+2}\cdot\frac{1}{D}=K_2$	K'_2	$\frac{K_2-K'_2}{K_2}.100$	$\frac{K_2-K''_2}{K_2}.100$
Glass	100·00	0·00	0·00	1·4590	2·213*a*	·2074	·2074	0·00		·12354	·12354	0·00	
	51·85	48·15	0·00	1·6280	2·904	·2163	·2163	0·00		·12220	·12220	0·00	
	0·00	100·00	0·00	----	----	---	·2260	0·00		----	·12077	----	
	59·95	0·00	40·05	1·5801	2·758	·2103	·2095	+0·38		·12070	·12025	+0·36	
	0·00	0·00	100·00	----	----	----	·2127	0·00		----	·11534	----	
	46·50	50·00	3·50	1·6410	2·953	·2171	·2168	+0·13		·12217	·12190	+0·22	
	45·00	40·00	15·00	1·6392	2·967	·2154	·2157	−0·13		·12130	·12120	+0·08	
	50·20	24·80	25·00	1·6225	2·920	·2132	·2133	−0·05		·12069	·12081	−0·10	
α—Ca_2SiO_4	35.00	65·00	0·00	1·724*a*	3·27*a*	·2214			− 0·86	·12130			+0·36
β—Ca_2SiO_4	35·00	65·00	0·00	1·728*a*	3·28*a*	·2219			− 1·09	·12143			+0·26
γ—Ca_2SiO_4	35·00	65·00	0·00	1·646*a*	2·974*a*	·2172			+ 1·05	·12204			−0·24
Quartz	100·00	0·00	0·00	1·5472	2·652*a*	·2066			+ 0·53	·11961			+3·20
Tridymite	100·00	0·00	0·00	1·483*a*	2·318*a*	·2083			− 0·43	·12319			+0·30
CaO	0·00	100·00	0·00	1·832*b*	3·316*a*	·2509			−11·02	·13266			−9·80
Periclase	0·00	0·00	100·00	1·734*b*	3·614*b*	·2031			+ 4·51	·11091			+3·84

a. The lime-silica series of minerals, this Journal (4), xxii, 265, 1906. *b.* Unpublished data. The probable error for the refractive index of CaO and periclase is ±0·005.

great as −11 per cent, as in CaO. The percentage of difference for the n^2 formula may likewise be positive or negative and reaches a value of 9·8 per cent for CaO.

Summary.

A study of the refractive indices and densities of silicate glasses and of artificial minerals was made to test the formulae of Gladstone and Dale and of Lorentz and Lorenz. Neither the refractive indices nor the specific volumes of the glasses are strictly additive functions, but there may be an increase or a decrease of volume and a corresponding decrease or increase of the refractive index. The specific refractivity computed from either formula is sensibly additive for the glasses and nearly so for the isomorphous series of soda-lime feldspars, but when crystals are compared with glasses of the same composition, or with other crystals, the values of the specific refractivity, computed from either formula, may differ by as much as eleven per cent. They are usually higher for the glasses. One formula appears to hold as well as the other, but the formula of Gladstone and Dale has the advantage of simplicity.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., May, 1909.

ART. XXIX.—*Note on the Miocene Drum Fish—Pogonias multidentatus* Cope; by BURNETT SMITH.

Introduction.

THIS rare species of the Virginia Miocene was originally described by Cope in 1869* and in 1908 the type was figured the first time by Hussakof† in the catalogue of fossil fishes published by the American Museum of Natural History. As far as the writer can learn, the type specimen has remained, for nearly forty years, the only known example of the species and it has always been regarded as a "left superior pharyngeal."

Another specimen of a pharyngeal plate obviously referable to *Pogonias* was recently collected by the writer from the Miocene of Maryland. It is apparently identical with Cope's species though the pattern of the bean-like crushing teeth differs slightly from that of the type. The chief points of interest attaching to this second specimen are the following: (1) it gives us slight but much needed information as to the range and distribution of the fossil Drums, and (2) it furnishes additional data for working out one or two points in the structure of the pharyngeals which up to now have remained obscure. Taking up the second of these considerations, we find that, strangely enough, the type has always been interpreted as a "left superior pharyngeal." It is indeed a part of the upper pharyngeal crushing pavement, but instead of being situated on the left side it was on the right side and furthermore represents only one of the three well-defined pharyngo-branchial plates which occur on either side in the pharynx of *Pogonias.*

Comparison of the Pharyngeal Teeth of Pogonias, Cynoscion, and Micropogon.

In order to understand the osteological value of the known parts of the fossil *Pogonias multidentatus* it is necessary to review briefly the conditions met with in the branchial arches of some of the recent Sciænidae. In this family we find that the different genera manifest a great variety in the form and structure of the pharyngeal teeth. In some the pharyngeal plates are set with simple sharp denticles: others have in place of denticles blunt bean-like crushing elements, while between these two extremes we find forms whose pharyngeals are

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* Cope, E. D., Proc. Bost. Soc. Nat. Hist., xii, p. 310.

† Hussakof, L., Bull. Am. Mus. Nat. Hist., vol. xxv.

adapted for either cutting or crushing. The most casual study of such a series suggests that the crushing type has resulted from a modification of the plate, which is covered with denticles. For this reason it is advisable to consider the pharyngeals of some sciænoid genus which is primitive in this respect (*Cynoscion*) and compare them with those of a less primitive form (*Micropogon*), and finally with those of a highly specialized form (*Pogonias*). The species which have been selected for this purpose are *Cynoscion nebulosus* (C. and V.), *Micropogon undulatus* (L.) and *Pogonias cromis* (L.).

The Lower Pharyngeal Plates.—In *Cynoscion nebulosus* the lower pharyngeals differ little from those of the normal teleost fish. They represent the inward plate-like expansions from the rudimentary fifth cerato-branchial, are not fused but remain distinct (right and left), and are covered by sharp backwardly curved denticles which are largest along the inner (median) anterior margin of each plate. In *Micropogon undulatus* the same general shape prevails but each plate is proportionately broader and heavier. When, however, the dental elements of the plates are examined we find a marked change from the condition observed in *Cynoscion*, for in *Micropogon* the denticles are much fewer, and though still small and sharp on the lateral (outside) and postero-lateral regions they have become large and blunted on the anterior inner (median) border. If now we extend our comparison to *Pogonias cromis* we find that the inwardly directed plate-like portion of each fifth cerato-branchial has expanded until it meets its fellow on the opposite side and is firmly united by suture with it. In addition each bone has developed on its under surface a prominent process directed downward, forward, and outward for the attachment of the powerful muscles needed in the operation of the fused plates. In conjunction with this fusion and strengthening the functional surface has developed bean-like crushing teeth. These are largest along the median (inner) margin of each one of the plates and decrease in size forward, backward, and outward. A few sharp denticles are still retained on the postero-lateral margins of each member, but the transition from sharp denticles to crushing elements can only be well seen in young examples of the species (fig. 3).

The Upper Pharyngeal Plates.—The upper pharyngeal plates of *Cynoscion nebulosus* exhibit no marked divergence from the normal teleost type. There are three well-marked upper plates on each side all covered with sharp backwardly curved denticles. The anterior plates (right and left) are narrow, lie forward and outside of the second pair of plates, and are directed forward and inward. The second pair of plates are the largest of the three and the denticles which they bear on their inner margins excel in size those of either the first or third pair. The posterior pair of plates are larger than the anterior pair but the denticles on their inner margins are very weak.

In *Micropogon undulatus* the plates of the second pair have increased in size at the expense of those of the first and third pairs. It is true the third (posterior) pair are not greatly reduced but their surfaces are covered with but small and weak denticles. The plates of the first (anterior) pair are much reduced in size and covered with weak denticles. The plates of the second pair are large, the outer (lateral) margins bear fairly sharp denticles while the inner (median) and central regions carry denticles which are larger and more blunt.

Turning now to the superior pharyngeals of *Pogonias cromis*, we find that the second pair of plates is proportionately much larger in size, while on the other hand the first and third plates are proportionately much smaller, being in each case narrow crescentic elements which are closely applied to the curved anterior and posterior margins of each plate in the second pair. These plates of the first and third pairs carry weak degenerate denticles. In *P. cromis* it is the second pair of plates which command our attention, for these are abnormally large in size and the denticles have for the most part been changed into blunt crushing elements. These bean-like teeth are largest along the inner margin of each plate midway between its anterior and posterior ends. From this region (on each plate) the teeth become smaller as we pass forward, backward, and outward. In addition as we go outward the typical bean-like condition is less and less marked, the teeth becoming gradually less and less blunt until we reach a small patch on the extreme outer margin which still retains the primitive sharp denticles. As might be expected, this transition between denticles on the one hand and crushing teeth on the other is much more evident in the plates of young individuals of *Pogonias cromis;* for the old examples of the species have but a relatively small denticled area and only a few transitional teeth (figs. 7 and 8).

Comparison of the Pharyngeal Teeth of Pogonias cromis and Pogonias multidentatus.

As stated above, the Miocene *Pogonias multidentatus* Cope is known by but two specimens. The type is a right superior pharyngeal from Nomini Cliffs, Westmoreland County, Virginia, and the other specimen is a left superior from the St. Mary's Formation of St. Mary's River, Maryland. Though the fossils are fragmentary, there can be no question as to their osteological value when we compare them with the corresponding parts which have been taken from the branchial arches of the recent *P. cromis* (L.).

Considering first the type of *Pogonias multidentatus*, we see that the bean-like crushing elements have all disappeared leaving only their sockets, while the plate itself has lost much of its outer and posterior portions. Some of the anterior part is likewise gone. On its dorsal surface the most striking points observed are (1) the ridge on the anterior central portion of the plate leading backward to the knob, which in the recent Drum serves for the attachment of the second epibranchial; (2) a portion of the large rounded knob at its posterior extremity, which in the living form furnishes the surface for the attachment of the broadly expanded proximal end of the fourth epibranchial; and (3) the strong ridge and process on the median margin, which is for muscular attachment. These three features are unmistakable and can all be checked with similar ones in the corresponding plate of *P. cromis*. Especially is this true for the large posterior knob, whose surface bears the same minute wavy ridges which are found in the living form.

When, now, we examine the dorsal surface of the Maryland fossil, we find, in spite of its fragmentary condition, that it agrees in every structural feature with the second left superior pharyngeal plate of *P. cromis*, and that there can be no question of the position which it occupied in the pharynx. The broken surface along the inner margin shows that the dorsally directed ridge was here well developed. The ridge which led to the knob for the second epibranchial attachment is unusually sharp and strong, much more so than in the type, and in this respect it closely approaches the condition observed in immature examples of the recent *P. cromis*.

Range and Probable Evolution of Pogonias.

In Dr. Hay's "Bibliography and Catalogue of the Fossil Vertebrata of North America"* two species of *Pogonias* are listed. The first of these, *P. cromis*, is mentioned by Leidy† as being found in the sands of the Ashley River, South Carolina; the second, *P. multidentatus*, was described by Cope as having come from the Miocene Cliffs of Nomini, Westmoreland County, Virginia. Inasmuch as the Calvert, Choptank, and St. Mary's strata are all extensively exposed at this locality,‡ it is unfortunately impossible to tell from Cope's descrip-

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* Bull. U. S. G. S. No. 719, Washington, 1901.

† Indications of Twelve Species of Fossil Fishes, Proc. Acad. Nat. Sci., Phila., vii, pp. 395–97.

‡ Md. Geol. Surv. Miocene, pp. lxxix and lxxx.

tion just which one of these Miocene horizons furnished the fossil. It is probable, however, that the type came from the St. Mary's formation, for this is the one in which the species has been found in Maryland.

The very meager fossil material* at the writer's disposal is hardly sufficient to illustrate any evolutional changes which may have taken place in the genus during its geological range. It is, therefore, to be regretted that we have, as yet, no means of checking the probable phylogeny which is suggested by an ontogenetic series of the pharyngeals of the recent *P. cromis.* It is evident from such a series that this peculiar type of crushing apparatus was developed by (1) the enlargement of the second pair of upper plates, (2) a progressive change from the inner margins outward from denticles to crushing teeth in both upper and lower plates, and (3) the fusion of the two lower plates. The enlargement of the second pair of upper pharyngeals was accompanied by a corresponding reduction of the first and third pairs together with a degeneration of their denticles. In both the second pair of upper plates and in the fused lower plates the young examples of this species exhibit every gradation between sharp denticle and blunt crushing tooth (figs. 3, 7). In the young the denticled area is relatively quite large, while in the old individuals a few blunt denticles only are found on the outer margins of the upper and on the postero-lateral angles of the lower fused plates (figs. 4, 8).

In conclusion, we can say that the peculiar crushing apparatus in the pharynx of *Pogonias* is, in all probability, the product of a series of evolutional changes which in a general way corresponded to those shown in the ontogeny of *P. cromis*, and it is also reasonable to suppose that the *Pogonias* stock, which had acquired its generic characters as far back as the Miocene, was preceded in time by forms the pharyngeals of which had reached a stage of specialization somewhat similar to that exhibited by *Micropogon undulatus.* Though recognizing fully the scantiness of the data, it is believed that the morphological gradations exhibited by the lower pharyngeals of *Cynoscion*, *Micropogon*, and *Pogonias* (Pl. I, figs. 1, 2, 3, 4), and by the upper pharyngeals (Pl. I, figs. 5, 6, 7, 8) of the same three genera, represent an approximation to the phylogenetic changes which have culminated in the crushing apparatus of *Pogonias.*

Acknowledgments are due to Prof. Bashford Dean of the American Museum of Natural History for the loan of type material and to Mrs. Ethel Ostrander Smith for the careful execution of the drawings here reproduced.

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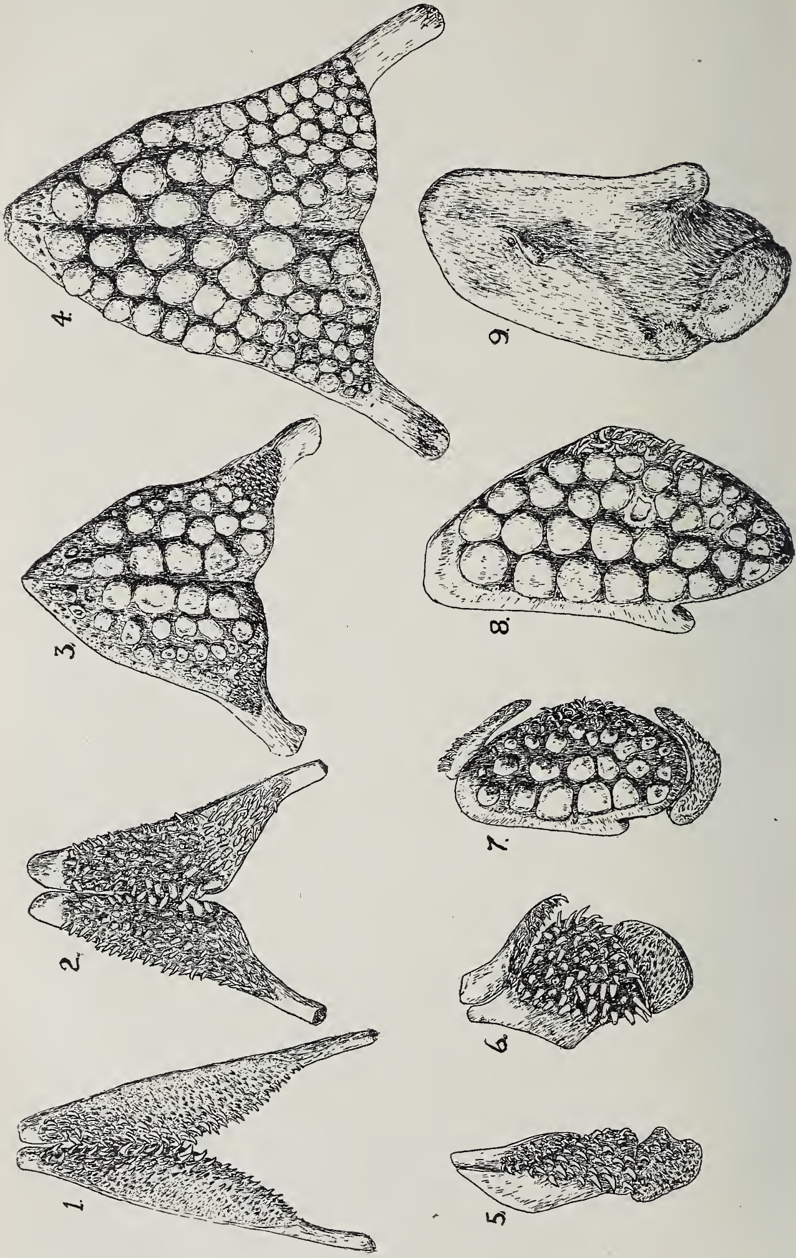
*I have not yet been able to locate Leidy's specimens from the Ashley River Sands.

Figs. 1–9.



Explanation of Figures 1–9.

Fig. 1.—*Cynoscion nebulosus* (C. and V.). Lower pharyngeals (functional surface). Length along outer margin = 42^{mm}. Plates covered with sharp denticles.

Fig. 2.—*Micropogon undulatus* (L.). Lower pharyngeals (functional surface). Length along outer margin = 24^{mm}. Plates relatively broader than in fig. 1, and with large blunt denticles on the inner margin of each plate.

Fig. 3.—*Pogonias cromis* (L.). Lower pharyngeals (functional surface) of young individual. Length along outer margin =38^{mm}. Plate fused. crushing teeth developed in the central region, but many sharp denticles still retained on the postero-lateral angles.

Fig. 4—*Pogonias cromis* (L). Lower pharyngeals (functional surface) of mature individual. Length along outer margin = 108^{mm}. An advance on the condition shown in fig. 3. Denticles replaced by crushing teeth, though these are sharper on the postero-lateral angles.

Fig. 5—*Cynoscion nebulosus* (C. and V.). Left upper pharyngeals (functional surface). Length = 28^{mm}. All three plates covered with sharp denticles.

Fig. 6.—*Micropogon undulatus* (L). Left upper pharyngeals (functional surface). Length = $17{\cdot}3^{mm}$. Second plate proportionately larger than in fig. 5, its denticles larger and more blunt on the inner margin.

Fig. 7.—*Pogonias cromis* (L.). Left upper pharyngeals (functional surface) of young individual. Length = 32^{mm}. Second plate proportionately very large with crushing teeth developed on its inner margin, but with many sharp denticles still retained on its outer margin.

Fig. 8.—*Pogonias cromis* (L.). Second left upper pharyngeals (functional surface) of mature individual. Length = 83^{mm}. An advance on the condition shown in fig. 7, the crushing teeth occupying nearly the entire plate with but a few denticles on the outer margin.

Fig. 9—*Pogonias cromis* (L.). Second left upper pharyngeal (dorsal surface) of immature individual showing the processes for the attachment of the epibranchials. The fourth arch attaches to the large rounded knob on the posterior margin, the third just forward and to the left, and the second arch is attached to the process shown in the forward central region of the plate. The process on the right is for muscular attachment. Length = 42^{mm}.

All the figures are arranged with the anterior end uppermost.

FIG. 10.

FIG. 11.

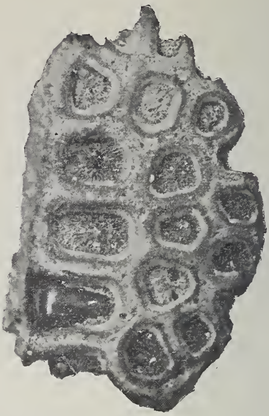


FIG. 10.—*Pogonias multidentatus* Cope. Type, Nomini Cliffs, Westmoreland County, Virginia. Second right upper pharyngeal (functional surface) with crushing teeth gone. Length = 49^{mm}.

FIG. 11.—*P. multidentatus* Cope. St. Mary's Formation, St. Mary's River, Maryland. Second left upper pharyngeal (functional surface) with crushing teeth gone. One successional tooth shows on the posterior part of the inner margin. Length = 35^{mm}.

FIG. 12.

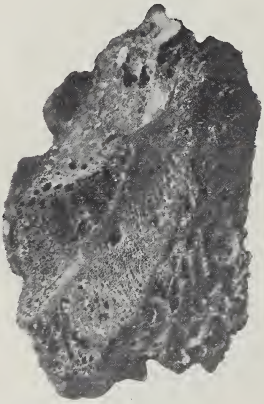


FIG. 13.

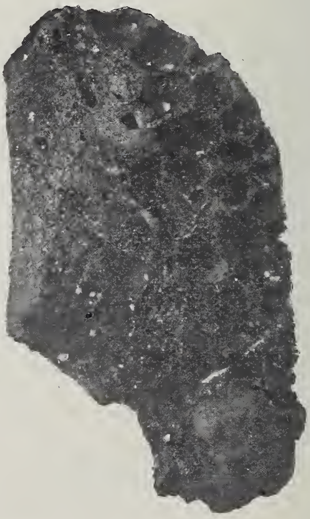


FIG. 12.—Dorsal surface of fig. 11 showing ridge leading to the second epibranchial attachment.

FIG. 13.—Dorsal surface of fig. 10, showing the large rounded knob on the posterio-lateral region which served for the attachment of the fourth epibranchial.

Figures all arranged with the anterior end uppermost.

ART. XXX.—*Description of Tertiary Insects, VII;* by T. D. A. COCKERELL.

ORTHOPTERA.

Tæniopodites gen. nov. (Orthoptera ; Acridiinæ).

TEGMINA long and comparatively narrow ; the inferior (anal) field reduced basally ; the costa rather full, arching near the base as in modern *Tæniopoda;* subcostal nervure closely appressed to radial, branching before the middle of the tegmen, the two branches running parallel and extremely close together; radius also with two parallel branches running very close together. Spots round and very distinct, much as in *Tæniopoda.* Although the spotting of the tegmen is very well preserved, most of the venation is obscure. The question may be raised whether there was not a vein (first subcostal) traversing the costal field as in living *Tæniopoda,* but not now visible. However, this vein (cf. *T. varipennis* Rehn, Proc. Acad. Nat. Sci. Phila., 1905, p. 405, f. 11) separates the spots of the costal field into two series, one above and one below; in the fossil no such separation is visible, and it is impossible to draw a line which could represent the vein, without passing through some of the spots. The radius is more like that of ordinary Acridians than *Tæniopoda.*

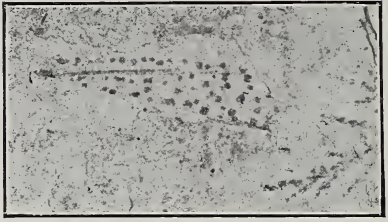
Tæniopodites pardalis sp. nov. Figure 1.

Tegmen about 32^{mm} long, width 5^{mm} about 6^{mm} from base, 8^{mm} about 25^{mm} from base ; spots as preserved reddish-brown, very distinct, half to 1^{mm} broad ; about 18 spots in costal field ; apex of costal arch about $3\frac{1}{2}^{mm}$ from base of tegmen. No other parts preserved.

Hab.—Florissant, Colorado, in the Miocene shales, Station 13 B (1908). The plant *Sabina linguæfolia* is on the same slab, nearly touching the tegmen. A photograph of the fossil was submitted to Mr. A. N. Caudell, who noted a resemblance to the spotted-winged species of *Tropidacris,* and also to the genera *Zoniopoda* and *Diponthus.* To me the tegmen seems exceedingly like that of *Tæniopoda* (a Mexican genus which enters the United States in southern New Mexico), and I believe there is really close affinity. A new generic name is proposed, because the venation is distinctive, and it is impossible to definitely refer the insect to any modern genus without a knowledge of the thoracic and other characters. In the maculation, and in the closely appressed veins, *Tæniopodites* presents a rather strong superficial resemblance to the Australian

Tettigoniid genus *Ephippithyta*, although in that genus, so far as known to me, there are no spots in the costal field.

Fig. 1.



Tæniopodites pardalis.

Gryllacris mutilata sp. nov. Figure 2.

♀. Length, exclusive of ovipositor, 33^{mm}; with ovipositor about 40; ovipositor strongly curved, its length along the curve slightly over 10^{mm}; length of head from vertex to apex of mandibles about 6^{mm}; length of prothorax 4½^{mm}. Tegmina and wings ample, the tegmina incomplete, but length about 38^{mm}; their markings consisting of fine transverse more or less broken reddish-brown bands producing a mottled effect; venation not well preserved, but essentially as in *Gryllacris*, the costal and subcostal veins each with strong oblique upper branches, the subcostal connected with the radius by straight transverse veins, the radius with strong oblique branches below.

Fig. 2.

Gryllacris mutilata Ckll.
A. Marking of tegmen. B. Ovipositor.

Hab.—Miocene shales at Florissant, Colorado, 1908 (*Geo. N Rohwer*). This is considerably larger than *G. cineris* Scudder. from Florissant, and is readily distinguished by the markings of the tegmina. Scudder remarks that *G. cineris*, as well as the European Tertiary species of *Gryllacris*, belong to the genus in a broad sense, and this is equally true of *G. mutilata.* It is more than likely that if these insects were perfectly preserved they could some of them be made the types of new genera; but it must be added that modern *Gryllacris* includes a great multitude (over 170) of species, having various diverse characters, and spread over the Neotropical, Australian, Oriental, and Ethiopian regions. The venation of some of these (e. g. *G. tibialis* Serv., *G. signifera* Stoll, *G. larvata* Rehn) is strikingly diverse, but is probably very variable within specific limits.

Palæorehnia maculata Ckll. Figure 3.

Florissant, in the Miocene shales. This species was described in Entomological News, 1908, p. 126, but although a figure was sent to the editor it was not published. A figure of the type specimen, showing the very characteristic markings, is accordingly now offered.

Fig. 3.

Palæorehnia maculata Ckll.

Diptera.

Tipula (?) hepialina sp. nov.

Pupa slightly over 21^{mm} long, nearly uniformly cylindrical, breadth in middle 5^{mm}; wing sheaths short, their tips about 7^{mm} from the cephalic end.

I had at first supposed this pupa to be lepidopterous, closely related to *Hepialus*. On examining it with a microscope, the compound eyes of the imago could be seen partially preserved, with many distinct facets, and these occupied a space apparently too large for the eye of any Hepialid, but accorded very well with the Tipulids. It was then noticed that the leg-sheaths extended far beyond the wing-sheaths, quite as in the

Tipulidæ, but not at all resembling Hepialidæ. The extreme brevity of the wing-sheaths also indicated a Tipulid, although the characteristic respiratory processes were not preserved. The pupa of *Dicranota* has five pairs of ventral pseudopods or tubercles (cf. Miall, Trans. Ent. Soc. Lond., 1893, pl. xiii); the fossil pupa has the three posterior pairs well represented, only between them is a third, so that each segment has a little row of three closely adjacent tubercles. There are very distinct lines marking the middle segments, as in the pupa of *Tipula flavicans* (cf. Needham, Bull. 68, New York State Museum, pl. 10).

Fig. 4.

Tipula hepialina Ckll.

Hab.—Miocene shales of Florissant, Colorado, Sta. 23 (*W. P. Cockerell*, 1908).

Tipula sp. nov.

A specimen in the Museum of Yale University, collected at Florissant (Miocene shales) by Mrs. C. Hill, is remarkable for the length of the legs. The venation cannot be made out, so it is hardly practicable to name the species. The specimen, a male, measures as follows in mm.:

Wing $14\frac{1}{2}$; body about 15; middle femur 10; middle tibia + tarsus $26\frac{2}{3}$; hind leg 44.

Tipula clauda Scudd., with wings about the same size, has the hind legs distinctly shorter; the combined femora, tibiæ and tarsi (measurements given separately by Scudder) measuring $37{\cdot}7^{\text{mm}}$. None of the Scudderian species show such measurements as ours, which is presumably new.

Mr. D. W. Doane kindly examined the legs of the living species of *Tipula*, and found that some have them fully as long. Thus he found *Tipula infuscata* ♂ to measure as follows in mm.: wing 16; body 16; middle femur 13; middle tibia + tarsus 30; hind leg 56.

ART. XXXI.—*A Method for the Iodometric Determination of Silver Based upon the Reducing Action of Potassium Arsenite*; by ROWLAND S. BOSWORTH.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccii.]

IT is well known that an ammoniacal solution of silver arsenite deposits metallic silver when the ammonia is evaporated by boiling. During this reaction, by which the silver salt is reduced, the arsenious acid becomes oxidized to the higher condition of oxidation, where arsenic has a valence of five, according to the equation

$$2Ag_2O + As_2O_3 = As_2O_5 + 4Ag.$$

The present paper deals with some work done with the purpose of determining whether this reaction was quantitative and of devising a rapid iodometric method for the determination of silver based upon the reduction of the silver salt to the metal.

Experiments were first performed upon a silver nitrate solution of known strength according to the following plan: To a definite portion of a standard solution of silver nitrate was added a known volume of a standard potassium arsenite solution in excess of the amount necessary to reduce the silver salt present. Ammonia was then added in sufficient quantity to dissolve the precipitate formed, and the resulting solution was diluted to 100^{cm^3} and boiled until the escaping vapor gave no test for free ammonia with moistened litmus paper. The solution, out of which metallic silver had then separated, was filtered, cooled, and made faintly acid in order to neutralize any possible trace of ammonia which might remain. After making alkaline with sodium bicarbonate, the excess of potassium arsenite was titrated with N/10 iodine. The silver value of the iodine used was subtracted from that of the potassium arsenite originally taken, and the result used as a measure of the silver present. In Table I, A, are given the results of experiments performed in the manner described above.

The effect was next tried of the use of sodium bicarbonate as a means for producing alkalinity in place of the ammonia. The following procedure was used: To a solution of silver nitrate was added an excess of standard potassium arsenite solution. The mixture was made alkaline by means of 25^{cm^3} of a saturated solution of sodium bicarbonate, diluted to 100^{cm^3}, and boiled until the precipitate of silver arsenite was converted to metallic silver. The solution was then filtered and acidified, in order to break up the neutral carbonate formed by boiling the bicarbonate. Finally the solution was made alkaline with sodium bicarbonate and the potassium arsenite present was titrated with N/10 iodine, the titration giving a measure of the silver originally taken. The details of these experiments are given in Table I, B.

TABLE I.

	KH_2AsO_3 added		I_2 used			
Silver taken grm.	cm³.	Silver value grm.	cm³.	Silver value grm.	Silver found grm.	Error in terms of silver grm.
			A			
		Use of NH_4OH with filtering				
0·1054	20	0·2000	8·53	0·0949	0·1051	−0·0003
0·1054	20	0·2000	8·52	0·0948	0·1052	−0·0002
0·1054	30	0·3000	17·42	0·1939	0·1061	+0·0007
0·1159	20	0·2000	7·60	0·0846	0·1154	−0·0005
0·1054	21	0·2100	9·37	0·1043	0·1057	+0·0003
0·1054	20	0·2000	8·48	0·0944	0·1056	+0·0002
			B			
		Use of $NaHCO_3$ with filtering				
0·1054	15	0·1618	5·65	0·0571	0·1047	−0·0007
0·1054	23	0·2481	14·14	0·1430	0·1051	−0·0003
0·1054	12	0·1295	2·40	0·0243	0·1052	−0·0002
0·1054	15	0·1618	5·60	0·0566	0·1052	−0·0002
0·1054	15	0·1618	5·55	0·0561	0·1057	+0·0003
0·1054	20	0·2158	10 91	0·1104	0·1054	±0·0000
0·2635	35	0·3776	11·33	0·1146	0·2630	−0·0005

Since the precipitate of metallic silver, in the experiments of both A and B, was in a well coagulated condition, experiments were carried on in which filtration was omitted, the titration being made in the presence of the precipitate. The results given in Table II, A and B, show that the precipitate has no appreciable effect upon the titration. If nitric acid were present in the solution of the silver salt, as is usually the case in analysis, it would be converted to a nitrate by the addition of the alkali. In order to prove that the presence of a considerable amount of sodium nitrate would not hinder the reduction of the silver salt, determinations were made after the addition of two grams of that substance, with the uniformly good results shown in Table II, C.

Since in analysis it is often necessary to determine silver when copper or lead or both are also present in solution, and since silver can, with proper precautions, be separated from either of these metals by precipitation with hydrochloric acid, it seemed desirable to accomplish the reduction of silver when it was in the form of the chloride. Consequently, determina-

TABLE II.

	KH_2AsO_3 added		I_2 used			
Silver taken grm.	cm³.	Silver value grm.	cm³.	Silver value grm.	Silver found grm.	Error in terms of silver grm.
A						
Use of NH_4OH. Titration carried on in presence of the precipitate						
0·1054	20	0·2000	8·55	0·0952	0·1048	−0·0006
0·1054	20	0·2000	8·50	0·0946	0·1054	±0·0000
0·1054	23	0·2300	11·28	0·1256	0·1044	−0·0010
0·1054	20	0·2000	8·45	0·0941	0·1059	+0·0005
0·1054	20	0·2000	8·48	0·0944	0·1056	+0·0002
B						
Use of $NaHCO_3$. Titration carried on in presence of the precipitate						
0·1054	18	0·1800	6·80	0·0757	0·1043	−0·0011
0·1054	17	0·1700	5·81	0·0647	0·1053	−0·0001
0·1054	15	0·1500	4·00	0·0445	0·1055	+0·0001
0·1054	21	0·2100	9·45	0·1052	0·1048	−0·0006
0·1054	25	0·2500	13·00	0·1447	0·1053	−0·0001
0·1054	31	0·3100	18·40	0·2048	0·1052	−0·0002
C						
Use of $NaHCO_3$. 2 grms. of $NaNO_3$ present. Titration carried on in presence of precipitate						
0·0949	21	0·2100	10·42	0·1160	0·0940	−0·0009
0·1054	21	0·2100	9·43	0·1050	0·1050	−0·0004
0·1265	20	0·2000	6·60	0·0735	0·1265	±0·0000
0·1686	21	0·2100	3·80	0·0432	0·1678	−0·0008
0·1054	15	0·1500	4·08	0·0454	0·1046	−0·0008

tions were made according to the following plan, the details of the experiments being given in Table III, A. From a known amount of a standard solution the silver was precipitated with hydrochloric acid, and filtered upon asbestos. The precipitate was then acted upon by strong ammonia, the mixture being allowed to stand until the silver chloride was completely dissolved. The solution was diluted to 100^{cm^3} and reduction accomplished by adding an excess of standard potassium arsenite, and boiling the resulting solution. The excess of potassium arsenite was subsequently titrated according to the procedure outlined previously in this paper. In Table III, B, are details of determinations similarly made, in which the silver was separated from 0·09 grm. of copper. The experiments in Table III, C, illustrate the separation of silver from 0·2 grm. of lead, and in the experiment recorded in D the silver was precipitated from a solution containing 0·09 grm. of copper and 0·2 grm. of lead.

From the results recorded in this paper, it is evident that silver can be easily and accurately estimated, either in solution

TABLE III.

Silver taken grm.	KH_2AsO_3 added		I_3 used		Silver found grm.	Error in terms of silver grm.
	cm.	Silver grm.	cm.	Silver grm.		
A						
Reduction of precipitated AgCl						
0·1017	15	0·1619	5·40	0·0599	0·1020	+0·0003
0·1017	15	0·1619	5·44	0·0603	0·1016	−0·0001
0·1017	15	0·1619	5·40	0·0599	0·1020	+0·0003
0·1017	15	0·1619	5·42	0·0601	0·1018	+0·0001
0·1017	17	0·1834	7·44	0·0825	0·1009	−0·0008
B						
Reduction of AgCl precipitated in the presence of 0·09 grm. of copper.						
0·1017	15	0·1619	5·41	0·0600	0·1019	+0·0002
0·1017	15	0·1619	5·44	0·0603	0·1016	−0·0001
0·1017	15	0·1619	5·39	0·0598	0·1021	+0·0004
C						
Reduction of AgCl precipitated in the presence of 0·2 grm. of lead						
0·1220	16	0·1726	4.57	0·0507	0·1219	−0·0001
0·1108	15	0·1619	4·60	0·0510	0·1109	+0·0001
D						
Reduction of AgCl precipitated from a solution containing 0·09 grm. of copper and 0·2 grm. of lead						
0·1017	15	0·1619	5·45	0·0604	0·1015	−0·0002

or in the form of the precipitated chloride, by adding an excess of standard potassium arsenite, boiling in alkaline solution to accomplish the reduction of the silver salt to metallic silver, and titrating the excess of potassium arsenite with iodine. The silver value of the iodine used is to be subtracted from that of the potassium arsenite originally taken, the result giving the amount of silver present.

SIMON NEWCOMB.

THE death of Simon Newcomb at his home in Washington on July 12, 1909, after a long and painful illness, terminated a life of extraordinary activity. His last contribution to his theory of The Motion of the Moon was finished a few weeks only before his death and was consciously hastened on account of his knowledge of the speedy approach of the end.

Simon Newcomb was born in Wallace, Nova Scotia, March 12, 1835. His father, John Benton Newcomb, was of American descent whose ancestors had settled in Canada in 1761.

He returned to the United States in 1852 and was followed in the succeeding year by Simon Newcomb, who, like his father, had been a teacher in Canada. For the next two years the young Newcomb taught school in Maryland and, while thus engaged, awakened the interest of Joseph Henry, the Secretary of the Smithsonian Institution, by means of a mathematical paper which was submitted to him. Henry secured for the young teacher an appointment as a computer in the U. S. Nautical Almanac, which was then published at Cambridge. While here he became a student in the Lawrence Scientific School, which completed his academic life until he returned to it as a Professor of Mathematics and Astronomy at Johns Hopkins University. This chair he held from 1884 until 1894.

While occupying the position of a computer in the Nautical Almanac Office, Newcomb published a paper on the orbits of a number of the asteroids which at once secured for him a world-wide reputation as a master in this difficult field of research and in which he was destined to lead his contemporaries. His exceptional merits were quickly recognized and he was given, in 1861, an appointment as a professor of mathematics in the U. S. Naval Academy with an assignment to duty in the Naval Observatory. This title he held until 1877, when he became Senior Professor of Mathematics. He retired in accordance with the law at the age of sixty-two, in 1897. During this period of twenty years Professor Newcomb was Director of the American Ephemeris and Nautical Almanac.

While connected with the Naval Observatory, Newcomb, in pursuit of his favorite study, advanced observational science in a remarkable degree. In order to secure better values of the masses of Uranus and Neptune, essential to his great project of perfecting the tables of the Solar System, it was necessary to have more perfect observations of the satellites of these two planets, and there were no telescopes in existence adequate to this end. This prompted him to a careful study of the best type of instrument for such observations, together with the probable limitations of the contemporary optical art, finally fixing upon a refractor of twenty-six inches aperture, for the construction of which he obtained a grant from Congress. This, the first of the great modern telescopes, was completed in 1876 and was made famous in August of the following year by the discovery of the two satellites of Mars by Professor Asaph Hall. Meanwhile, Newcomb had observed the satellites of the two most remote planets of our System and employed his results in perfecting the tables for Uranus and Neptune, which have been used by all astronomers from the moment of their first appearance. The knowledge and experience acquired by Newcomb in his studies of telescopes made him an invaluable adviser in the equipment of the Lick Observatory.

This grand project of Newcomb led to two other extensive investigations which a man of less intellectual breadth and courage might have been expected to leave to others. For a long time there had been growing a doubt among astronomers as to the accuracy of the accepted value of the fundamental unit of the Solar System, namely, the true distance of the Sun from the Earth. This value was established by Encke from observations of the transits of Venus. Newcomb undertook the enormous labor of a complete rediscussion of this result from all the original records of the observations of transits of Venus previous to that of 1882, and, from a judicial weighing of probabilities which has commanded admiration from all competent critics, derived a value which was almost identical with that now accepted.

An independent method of establishing the same constant is derived by combining the observed aberration of light with its measured velocity. Professor Michelson, then an Ensign in the Navy, had improved Foucault's method of measuring the velocity of light and, by a series of skillful experiments, had added greatly to the precision of our knowledge of its value. Newcomb secured Michelson's aid and a grant of money from Congress to meet the expenses of a continuation of these measures on the largest effective scale. The results of such coöperation were most brilliant, and they attach the name of the astronomer to the historical determinations of the great constant of physical science as well to that of astronomy.

The world of science has not failed to recognize and reward, as far as possible, the great services of Simon Newcomb. In our own country hardly a university of prominence has withheld from him its highest honors. The Institute of France made him a correspondent in 1874, and in 1893 elected him as one of its associates, an honor accorded to only eight outside of France. An Officer of the Legion of Honor in 1893, he was made a Commander in 1907. In our own country Professor Newcomb was very active in the National Academy, in the American Philosophical Society, in the Astrophysical Society, and in others. A man delightfully simple in manner and cordial in intercourse with other men of science, it was always an inspiration to younger men to converse with him.

C. S. H.

Samuel William Johnson, Professor of agricultural chemistry in the Sheffield Scientific School of Yale University, died on July 21, in his eightieth year. A notice is deferred till a later number.

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FOURTH SERIES

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NEW ARRIVAL

OF

Rare and Choice Minerals.

Adularia, Switzerland; Apatite, crystal, 2¼x2, pinkish, Mesa Grande, Saxony, Connecticut, Tyrol; Alexandrite, Ural Mts.; Argyrodite, Freiberg; Apophyllite, Bombay; Arsenopyrite, Freiberg; Amethyst, parallel growth crystals 2-inch to 6-inch long, Cripple Creek; Altaite, New Mexico; Atacamite, Australia; Bournonite, Nassau, Hungary, England; Boulangerite, Bohemia; Binnite, Binnenthal; Bismuth, Japan; Cerargyrite, Chili, Nevada; Chrysoberyl, Finland, Connecticut; Cabrerite, Greece; Cassiterite, Saxony, Bohemia; Crocoite, Tasmania, Ural Mts.; Chloritoid, Tyrol; Carnotite, Telluride, Colorado; Cerussite, Broken Hill; Cuprite, Arizona; Celestite, Bristol; Calciovolborthite, crystallized, Telluride, Colorado; Calamine, Ogdensburg; Calaverite, Cripple Creek; Columbite, Conn.; Diamonds, loose crystals, Brazil, different forms; Datolite and Calcite, Bergen Hill; Eulytite with Bismite, Schneeberg; Elpidite, Greenland; Euchroite, Libethen; Embolite, Silver City, New Mexico; Emerald, Tyrol, Bogota, S. A., Ural Mts., N. Carolina; Eudialyte, Greenland; Erythrite, Saxony; Euclase, Capo do Lane, Brazil; Gold, Hungary, crystallized; Gadolinite, Sweden; Herrengrundite, Herrengrund; Haidingerite, Joachimsthal; Herderite, Auburn, Poland; Harmotome, Scotland; Iridosmine, Ural Mts.; Iodyrite, Broken Hill; Ilmenite, Connecticut; Jordanite, Binnenthal; Kongsbergite, Norway; Kallilite, Obersdorf; Linnæite, Westfalen; Livingstonite, Mexico; Lorandite, Macedonia; Manganite, long crystals, Saxony; Milarite, Switzerland; Mimetite, Freiberg; Monazite, Portland; Microlite, Virginia; Meliphanite, Brevig; Neptunite, San Benito; Niccolite, Eisleben; Parisite, Columbia; Pyromorphite, Ems, Cornwall; Pharmacosiderite, Cornwall, Saxony; Pucherite, Schneeberg; Pyrargyrite, Mexico, Saxony; Pyrargyrite with tetrahedrite, Nevada; Plattnerite, Idaho; Pollucite, Paris; Pseudomalachite, Germany; Phlogopite, Ogdensburgh; Reinite, Japan; Rathite, Binnenthal; Stephanite, St. Andreasberg, Mexico; Scheelite, Bohemia; Scorodite, Saxony, Cornwall; Smaltite, Schneeberg; Sylvanite, Cripple Creek, Transylvania; Stilbite, Bombay; Tiemannite, Hartz; Torbernite, Cornwall, Saxony; Tourmaline, Mesa Grande, Connecticut, Franklin Furnace; Tetrahedrite, England, Hungary, Utah; Uwarowite, Ural Mts.: Uraninite, Portland; Vivianite, Colorado; Vanadinite, Kelly, Mexico, Scotland; Zincite crystals in matrix, Franklin Furnace; Zeunerite, Schneeberg; Zeophyllite, Bohemia; Anatase, Binnenthal; Benitoite, San Benito; Cobaltite, Cobalt, Ontario; Cinnabar, China, Spain, Adria; Dioptase, Siberia, Fontainebleau, France; Tellurium, Cripple Creek.

A. H. PETEREIT,

81—83 Fulton Street, New York City.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXII.—*The Binary Systems of Alumina with Silica, Lime and Magnesia*; by E. S. Shepherd and G. A. Rankin. *With Optical Study*, by Fred. Eugene Wright.

According to the calculation by Clarke,* the order of relative importance of the oxides which make up the rock-forming minerals stands,—silica, alumina, oxides of iron and lime, etc. It seems desirable to begin with the study of the systems of alumina, silica and lime, leaving the iron oxides until more experience with the difficulties of this work should enable us to meet the increased difficulties which are introduced by the different oxidation stages of iron. The first paper of the series† was published some time ago. We have now to present the result of experiments with three other groups of oxides.

The interest aroused by the study of the lime-silica series, not only among those engaged in pure science, but also among many in commercial work, would seem to warrant devoting some space not only to the methods but also to the limitations of this kind of investigation.

In developing a system of such immense usefulness, it is of the greatest importance that those who are interested in the application of physical chemistry to extreme cases of rock magmas shall have a firm grasp of the limitations, both of the theory and experimental possibilities. None of the laws of physical chemistry can be applied to such extreme conditions without some modification.

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* Data of Geochemistry, F. W. Clarke, Bull. No. 330, U. S. Geol. Survey, 1908.

† The Lime-Silica Series of Minerals, Day, Shepherd and Wright, this Journal (4), xxii, 265, 1906.

As has often been said, the geologist is dependent on the petrographic study of rocks which have passed through many changes. A study of relatively simple two- and three-component systems shows the futility of attempting to *deduce* the past history of any polycomponent system from its *final* condition. Petrographers have already observed the order of crystallization for certain minerals, but the exact correlation of this order with the composition of the rock remains to be determined. The phase rule shows that the first mineral to separate from a freezing solution depends primarily on the initial composition and only indirectly on the melting point of the mineral. Furthermore, it is always possible for a mineral to be redissolved after it has begun to separate and subsequently to reappear at a lower temperature. If the eutectic relation was the only one encountered in the study of minerals, the classification of rocks, as well as the interpretation of the occurrence of the femic and salic rocks, would be relatively simple. But studies of simple systems leave no room for doubt that the phenomena in a great rock magma are exceedingly complex, and we have no choice but to begin with the laboratory study (quantitative measurement) of relatively simple mixtures of pure minerals. We are entering upon a new science in which it is absolutely essential that we proceed in an orderly way through simple relations and conditions to those which are more intricate. Experiments on the rocks, if undertaken first, would be as futile as to design a power plant without a first acquaintance with the physical properties of materials.

Take another obvious instance. It is of course desirable to know the molecular weight of the various minerals, whether or not they dissociate in solution, and the effect of these phenomena on their inter-reactions. At the present time such questions are practically unanswerable. The molecular weight of salts in aqueous solution is determined by the lowering of the freezing point, but even at this low temperature and with the most delicate apparatus, an error of five per cent is regarded as doing very well. Not only must the temperatures be measured to the nearest hundredth of a degree, but the formulæ have thus far been found to apply only to "infinitely" dilute solutions,—never over one per cent. Silicate melts are too viscous to be stirred, and freezing occurs in a region of variable temperature distribution and always over an interval of a whole degree or more. Furthermore, we have *as yet* no means of knowing that the *fundamental assumptions* underlying the Van't Hoff–Raoult relation hold true for silicates. We ought, therefore, to hesitate before forcing the results thus far obtained into formulæ which were deduced for wholly different conditions and which apply none too accurately even then. Obviously, the calculation of molecular weights from concentrations of ten, twenty, and even fifty per cent, as has sometimes been done, can serve no useful purpose.

A glance at the technique of measurement of conductivity in aqueous solutions will reveal how unwise are generalizations based on experiments with the conductivity of silicates. Maintaining a constant temperature throughout even a relatively small volume is extremely difficult at a temperature of 1200° C. Electrodes and containing vessels can not be maintained constant in shape or dimensions, nor can perfect or constant contact relations between the electrodes and the melt be assumed. Until such essential conditions can be supplied, we cannot hope to derive much useful data from merely passing the electric current through a silicate. The effect of high and varying viscosity on conductivity is unknown.

Pyrometry has made great progress in the last decade, and for temperatures below 1600° C. the thermoelement is capable of reading accurately to one-tenth of one degree. But it does not follow that all thermal phenomena in silicates are definable with this precision. The phenomena of melting and inversion, for example, seldom occur with sharpness enough to allow of their being determined within less than $\pm 1°$ for compounds, and $\pm 2°$ for eutectics. We must guard against the too common error of assuming that we have determined the phenomena with the accuracy with which we can read the scale of the instrument.

Above 1600° C. the optical pyrometer must be used, and the accuracy is much less. With the thermoelement the evolution or absorption of heat which occurs in a charge registers itself, leaving nothing to the judgment of the observer. With the optical pyrometer, as ordinarily used, the melting temperature must be inferred from the apparent fusion of the charge, and the observer is dependent upon his arbitrary judgment as to what constitutes fusion. Usually he cannot determine the beginning of fusion nor can he tell the exact point where the change is complete. Here again, not enough is known of the viscosity of the various mixtures to allow for its effect upon the phenomenon which the observer sees. As Day and Allen have shown,* albite retains its rigidity long after fusion (deorientation of crystal structure) is complete. Quartz acts in a similar manner. The different concentrations in mixtures show all gradations between this extreme viscosity and the extreme

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* Isomorphism and Thermal Properties of the Feldspars, Publications of the Carnegie Institution of Washington, No. 31.

fluidity, as in the case of Al_2SiO_5. The best the observer can do at present in the region above 1600° C. is to determine the maxima and eutectics. Determination of the liquidus is beyond our present facilities.

There is also a tendency to expect reactions to proceed with the same dispatch which we are accustomed to meet with in the case of aqueous solutions. This has not only never occurred in our experience, but unstable forms often require much urging to bring them into the stable condition.

The very first difficulty which we encounter is in obtaining pure homogeneous preparations with which to begin. The natural minerals are rarely pure enough to give constant data. A natural mineral melts at a given temperature, depending (as *indicated* by the Van't Hoff–Raoult law) upon the amount of impurity which it chances to contain; but the next specimen, having different impurities and in different amount, will melt at a different temperature. That is, the data obtained apply only to the specimen examined and furnish no basis for determining general relations.

The Chemical Purity of the Ingredients.—One must begin with the purest possible components. The oxides of lime, alumina and silica on the market are not usually pure enough. The influence of small amounts of impurities, 1 to 3 per cent, cannot be neglected. A glance at the slope of the freezing point curves shows at once that the presence of one per cent of impurity may cause a variation of five or ten degrees in the melting temperature.

Calcium carbonate can be obtained very pure, but high purity cannot be taken for granted without testing it.

The C. P. alumina of commerce is likely to contain ·5 to 2·0 per cent of alkalies, and one sample of especially pure (!) alumina contained over 3 per cent of SO_3. Baker and Adamson succeeded in making for us a hydrated alumina which contained only ·2 to ·4 per cent alkali, and this alkali was then reduced to less than one-tenth of one per cent by further purification in platinum.

Pure silica is obtained from quartz, carefully selected with the microscope, and treated with aqua regia.

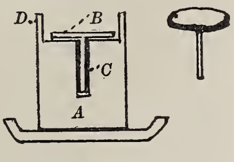
Magnesium carbonate usually contains from 1 to 3 per cent of $CaCO_3$, and this impurity is usually not mentioned in the manufacturer's analysis. In this case also, Baker and Adamson produced a special preparation of high purity.

Homogeneity of the Mixtures.—After pure materials have been obtained, we have next to obtain chemically homogeneous products. It has been found necessary to melt the charge at least three times with fine grinding and mixing between the fusions, in order to obtain a product which is chemically homogeneous. A conspicuous visible demonstration of the need for such careful preliminary mixing occurs with the composition Al_2O_3 8 per cent, CaO 69 per cent, SiO_2 23 per cent. As long as the mass is incompletely combined, quantities of calcium orthosilicate will disintegrate (dust), yielding a mixture of fine powdered orthosilicate and cinders of the more aluminous material. After three or four fusions and grindings, the charge remains solid, i. e., practical homogeneity has been secured. This shows that diffusion in silicate melts is extremely slow and emphasizes the necessity for the somewhat tedious care in preparation.

The effect of insufficient mixing on the observed melting points may be very great. Even in a sharply melting compound like anorthite, the cones prepared from the most carefully mixed oxides often melt 20° or more below those made from previously combined oxides. Here the heat of combination is evidently dominant. Obviously, quite the reverse might happen with other mixtures. One immediate consequence of this is that experiments in which the Seger cone method is employed for the measurement of temperature must always be made with carefully mixed and combined charges. It is also clear that comparison of the bending of a Seger cone with the bending of a cone of wholly different mixtures may mean very little, for the viscosities of the different mixtures bear no definite relation to each other, and viscosity is the chief factor in the bending of these cones.* Thus minerals like quartz or albite will retain their stiffness far above their melting points, i. e., after their crystalline structure is entirely gone.

Apparatus.—Those portions of the series which melt below 1600° were determined by the thermoelectric method described in the various publications from this laboratory. Above 1600° only the optical method described in the lime-silica paper is available, i. e., an optical pyrometer (Holborn and Kurlbaum type) sighted on a strip of platinum or iridium. We have found it useful to make a small tack of platinum, as figured (fig. 1, B). This tack has a polished upper surface upon which to sight. The prepared charge is moulded into a cylinder (A) of the shape shown; the shaft of the tack fits snugly into the hole (C) in the cylinder; the head of the tack (B) rests firmly on the flat surface of the charge, while the raised shoulder (D) diminishes the reflection from the walls of the furnace. If ideal conditions obtained, the tack would be invisible, i. e., we would have an absolute black body, but

Fig. 1.



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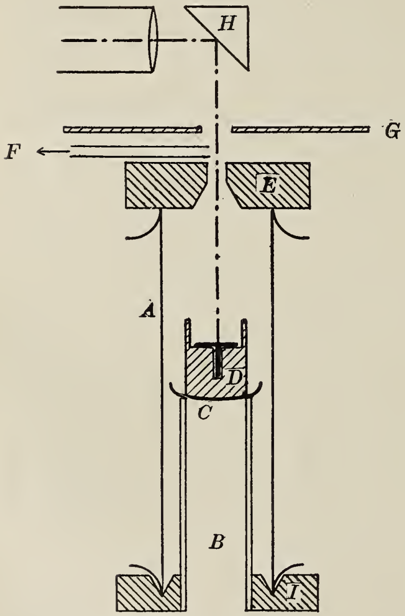
* See The Lime-Silica Series of Minerals, this Journal (4), xxii, 268.

at the melting point the retardation of the temperature of the charge, communicated along the shaft of the tack, should cause the head to flash, i. e., become visible. Although the condition of even approximate blackness is seldom attained in such furnaces, we were much assisted by this method of procedure.

At the present time observations of melting temperatures above 1600° are only determinable for the case of compounds at the maximum, and for eutectic compositions. The course of the liquidus cannot be established by any optical method yet devised. For that reason we have sketched all curves above 1600° in dotted lines to indicate that only the maxima and minima are determined. Of course the phases present along the liquidus can be determined microscopically, and this has been done in every case. The method of making these temperature observations is similar to that used on the orthosilicate of lime. A (fig. 2) is the tube of the iridium furnace; B, a magnesia cylinder on which rests the iridium crucible C. D is the cylinder whose melting temperature is desired, with the iridium tack in position. E is a magnesia lid with a small hole through which to observe the charge; F an exhaust tube to carry away the iridium vapors and heated air which would affect the prism H of the pyrometer. G is an asbestos shield to further protect the pyrometer. The bottom of the furnace is closed by the circular cup, I, thus preventing air currents from passing up through the furnace. If the furnace acted as a perfect black body, neither the metal tack nor the charge would be visible. When such blackness does not occur, the scale of a theoretically black body does not apply, and the pyrometer must be calibrated arbitrarily *in terms of the conditions in which it is used.* The difference between the theoretical and actual scales may reach 100° C. The necessity for frequent recalibration is also obvious.

Fig. 2.



This arbitrary calibration of the instrument was made with the help of certain fixed points. The melting temperatures of diopside and anorthite are now definitely known, and we are sure that the melting point of platinum is constant, though there is some doubt at to its exact temperature in degrees. We have assumed it to be 1750°. Diopside melts at 1395°, according to the values of Allen and White,* provisionally corrected by recent unpublished comparisons with the gas thermometer by Day and Sosman. On the same curve extrapolated, anorthite melts at 1542°. By calibrating the instrument in terms of these fixed points, the relative temperatures of our scale are definitely established. The absolute temperatures may shift with more accurate determinations of these fixed points.

The accuracy of the individual observations is determined by (1) the sharpness of the flash of the tack, and (2) by the delicacy with which the lamp filament can be matched up against the tack surface. In this work we found the points at which the filament was *distinctly* brighter or *distinctly* darker than the tack surface to lie 8 millivolts apart. The actual adjustment was ±2 millivolts, so that the maximum error of observation was ±20° and the probable error ±10° or less. The actual variations in the melting point observed for platinum were ±2 millivolts or 10°. At this temperature, therefore, the variation due to the material melted falls within the limits of error of the pyrometric system. The same is true of the anorthite and sillimanite. We feel justified in saying that the method is reliable, though rough and of limited usefulness compared with the thermoelement below 1600°. Several improvements have been suggested by this work and are now being tested.

Preliminary studies for locating the approximate position of maxima and minima were made in a 40^{mm} iridium tube furnace (Nernst type) by placing small amounts of the finely powdered and thoroughly combined charge on an iridium tray and exposing for a definite period at constant temperature. This temperature is then increased by degrees until the minima appear, after which the temperature is stepped up until the maximum is located. With sharply melting mixtures, and where there is a reasonably large difference of temperature between the maxima and minima, the *compositions* can be quite definitely determined. If, however, the eutectic is viscous, like that between Al_2SiO_5 and SiO_2, the minima can be located only approximately by this method. Similarly, where the compositions of the maximum and minimum are

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* This Journal (4), xxvii, 1, 1909.

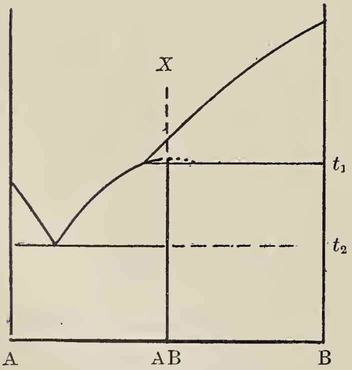
close together, like Al_2SiO_5–Al_2O_3, and the temperature difference is small, the exact location of the eutectic composition is very difficult to establish. Unfortunately, the microscope is also of little assistance in this case.

All such observations must be made in an oxidizing or neutral atmosphere; a reducing atmosphere not only reduces some of these oxides and silicates, but even where this is not the case, the flame playing about the furnace opening renders the optical pyrometer useless for exact measurements. A hydrogen atmosphere is perhaps the worst. At temperatures above 1000°, it reduces silica or silicates, setting free silicon which renders the platinum or iridium crucibles "hot short" and ultimately destroys them. This reaction is doubtless due to the silicon hydride, since it is by no means necessary that the silica and platinum be in contact in order that this destructive action occur. A platinum crucible in which a charge of silica was heated to 1100° in hydrogen, increased in weight by more than thirteen milligrams. On analysis, almost the theoretical quantity of SiO_2 was found. The crucible was highly crystallized and could be broken up to a coarse powder in the fingers. Wires less highly charged with silicon are very brittle when hot, even though not appreciably so when cold.

Carbon is known to react readily with lime above 1700° to give calcium carbide, so that a carbon atmosphere above 1200° introduces an undetermined error into the work.

One of the series studied (lime-alumina) presents the troublesome case of a compound unstable at the melting point. If the composition of the compound be X (fig. 3), then the first crystals to separate on the freezing of this mixture are, of course, B. At the temperature t_2 these crystals should combine with component A to form the compound AB. But it often happens that the crystals become coated over with the compound AB and are thereby removed from the action of component A. The result is that the charge freezes at t_1 to a mixture of A, AB, and B, which of course is unstable in a two-component system. Theoretically, if the charge were held for a long time at a temperature between t_1 and t_2, diffusion should cause all free B to disappear, so that the mass

Fig. 3.



when cooled down should consist entirely of the compound AB. By taking the fused charge of composition AB, grinding to a very fine powder and heating for a long time between temperatures t_1 and t_2, we were successful in bringing about this reaction in the case of $3CaO.Al_2O_3$.

Alumina-Silica.—In this series there is but one compound which is stable in contact with the melt. This is the mineral sillimanite, Al_2SiO_5, composed of Al_2O_3 62·85 per cent, SiO_2 37·15 per cent. This occurs in nature widely distributed. The same compound has been found by Mellor in the crystallized glaze of porcelain. The pure artificial compound is colorless and occurs in well crystallized prisms of density of 3·031, slightly lower than the natural mineral, which averages 3·32. Hardness is 6 to 7. The compound is unaffected by water, hot or cold, and is but very slowly attacked by acids or alkalies. Sillimanite is practically unaffected by HCl, HNO_3 or H_2SO_4, hot or cold, or by cold HF. It is decomposed slowly in mixed HCl and HF, and by fused Na_2CO_3. The melting temperature of the pure compound is 1811° C.

TABLE I.

a. Melting point fused sillimanite made from pure oxides.		*b.* Melting point of mixed and heated oxides of the same composition as *a.*	
Millivolts	T	Millivolts	T
·475	1812°	·472	1802°
·475	1812	·485	1850
·474	1810	·483	1850
·474	1810	·483	1850
Mean 1811°		·479	1833
		·480	1835

Table I, *b*, is given to show how great an error is introduced by observing incompletely combined oxides. These charges had been heated several times to about 1600° in the gas furnace, but still showed free silica and alumina. After fusion, they gave concordant results. The flash is also much sharper when the oxides are properly combined. It will be noticed that the observed melting temperature varies irregularly, and is not altogether dependent upon the rate of heating.

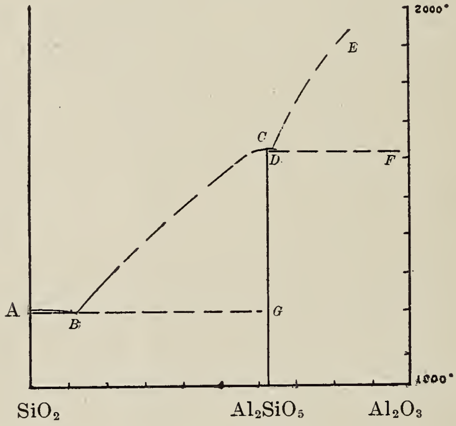
The eutectic Al_2SiO_5–SiO_2 is very hard to place, owing to the extreme viscosity of the silica. Heated for one hour at 1550° in a platinum furnace, nearby mixtures show no evidence of fusion. The 15 per cent and 20 per cent Al_2O_3 charges show traces of fusion before pure SiO_2. The eutectic must therefore fall at about 10 per cent and melt slightly below 1600° C. Throughout the range of concentrations from SiO_2 to $Al_2O_3.SiO_2$

cristobalite and sillimanite are the only phases. The eutectic for Al_2SiO_5–Al_2O_3 is only very slightly below the melting temperature of the compound. There is, however, a rapid rise of the liquidus beyond 65 per cent Al_2O_3, so that in default of a pyrometric method we must depend on the modified Joly method which indicates the location of the eutectic at about 64 per cent Al_2O_3.

Corundum occurs in all compositions between Al_2SiO_5 and Al_2O_3, and no phases other than sillimanite and corundum do appear. The optical properties of the sillimanite remain practically unchanged in the presence of SiO_2 or Al_2O_3. We accordingly infer that little or no solid solution of the component minerals in sillimanite occurs here.

The corundum shows slightly altered properties, and probably takes up a limited quantity of sillimanite in solid solution. The melting point of corundum lies above the safe working range of the iridium furnace, and it is hardly worth while to attempt determinations in the carbon furnace. The nature of the equilibrium diagram is shown in fig. 4.

Fig. 4.



Unstable forms.—The two natural minerals of the same composition as sillimanite are cyanite or disthene, and andalusite. Neither of these minerals occurs in igneous rocks and Vernadsky has shown* that both change to something like sillimanite at temperatures above 1300°. He also states that the change is accompanied by an *evolution* of heat. We have verified the change of form, but have not been able to detect any heat change. Our experience led to the conclusion that

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* Bull. Soc. Min., xii, 446; xiii, 257.

the inversion takes place so slowly as to completely veil the character of the corresponding heat change.

A very pure andalusite from Hill City, S. D.:

Heated	Temperature	Remarks
48 hours	1100°	Unchanged
62 "	1150°	"
168 "	1150°	"
28 days	900°	"
4 "	1500°	Much altered

If the transformation is reversible, the change is slow even at temperatures much above the supposed inversion point. All natural andalusite is contaminated with mica which masks the reaction. Using a flux in the hope of getting the transformation at lower temperatures, failed to yield satisfactory results.

Time	Flux	Temperature	Remarks
12 hours	NaCl	800°	Little altered
72 "	"	"	Andalusite still abundant
168 "	"	"	Andalusite still abundant. No sillimanite
48 "	CaV_2O_6	1000°	Andalusite still present. No sillimanite
48 "	"	900°	Little changed. No sillimanite
216 "	"	900°	Little changed. No sillimanite

At higher temperatures the andalusite is decomposed without forming sillimanite. Andalusite heated seven days at 400° in a bomb containing 10 per cent NaCl solution showed no change. The result indicates that andalusite changes to sillimanite at high temperatures, but with considerable difficulty. The reverse change, sillimanite-andalusite, does not occur under any conditions which we have yet tried.

Cyanite,—Like andalusite, cyanite is much contaminated with mica, rendering satisfactory thermal study of the natural mineral difficult. It is not possible to separate it completely by purification with aqua regia and cold HF. Its specific gravity is 3·5 – 3·7. Hardness = 4–5 or 6–7, depending on the direction with respect to the prism axis. Vernadsky found the mineral changing to sillimanite above 1300°. We have found the change to be slow, though more rapid than the change from andalusite to sillimanite.

Time	Flux	Temperature	Remarks
½ hour	None	1500°	Decomposed, but no sillimanite identifiable
7 days	"	1150°	But little changed
2 "	"	1150°	But little changed
2 "	"	1000°	Unchanged
28 "	"	900°	Little changed

Borax decomposes the mineral.

Time	Flux	Temperature	Remarks
12 hours	NaCl	800°	Unchanged
72 "	"	800°	Little changed
48 "	CaV_2O_6	1000°	Cyanite decomposed but no sillimanite formed

Cyanite is thus more readily decomposed than andalusite, but shows no sillimanite which can be determined with the microscope.

We have shown that at about 1300° both andalusite and cyanite change, the one into sillimanite and the other, from Vernadsky's density determination, probably into sillimanite, though badly formed. It is now in order to determine whether sillimanite, which is stable at high temperatures, will change into cyanite or andalusite at low temperatures.

Sillimanite shows no heat effect between 1100° and 1500°.

Time	Flux	Temperature	Remarks
168 hours	None	600°	Unchanged
96 "	"	1100°	Unchanged

Heated four days at 1000° with a small amount of borax, the crystals show slight attack, but are not destroyed, and no andalusite or cyanite appeared. Heated 48 hours at 1100° with CaV_2O_6, the powdered crystals were slightly attacked and *new crystals of sillimanite formed.* Working in steel bombs with various aqueous solutions, negative results were obtained.

Time	Flux	Temperature	Remarks
7 days	5% NH_4F	400°	The original grains are pitted, but no new crystals formed
6 "	10% NaCl	450°	Unchanged
7 "	10% KBr	400°	Slightly attacked

Heated thirty days in a long steel tube which allowed a continuous current of hot water (250°) to pass over the mineral and then to a cooler part of the tube, no alteration was produced.

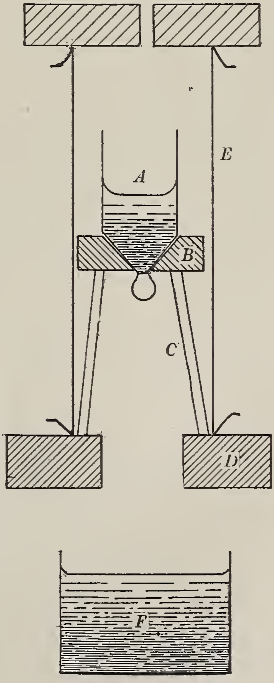
Thus at low temperatures no conditions were found under which sillimanite tended to change into andalusite or cyanite. Solutions of sillimanite in albite and borax gave always sillimanite. When fused sillimanite is rapidly cooled (quenched); it always crystallized as sillimanite.

It would be a waste of time to tabulate all of the metathetical reactions by which we have sought to produce these two unstable forms. After overcoming the great difficulties of finding a suitable vessel which will withstand the pressure of aqueous solutions at high temperatures, and which will not be attacked by the reagent, we have not yet been successful in our attempts to prepare andalusite and cyanite. Attempts to produce reactions between the hydrated oxide of silicon, i. e., the various hypothetical silicic acids, and alumina, hydrated or dry, gave no positive results. Certain reactions involving the attack upon anorthite and other minerals by $Al_2(SO_4)_3$ or $AlCl_3$, have yielded but little promise of success. $AlCl_3$ acting on anorthite gave small spherulites of which the determinable properties agree with andalusite, but these crystals were too small for positive identification. We did not obtain positive results by the action of fluxes on the oxides.

Incidentally, we observed the formation of meionite by crystallizing glass of that composition in a bomb with 10 per cent NaCl solution, and grossularite by the reaction of $AlCl_3$ on calcium orthosilicate.

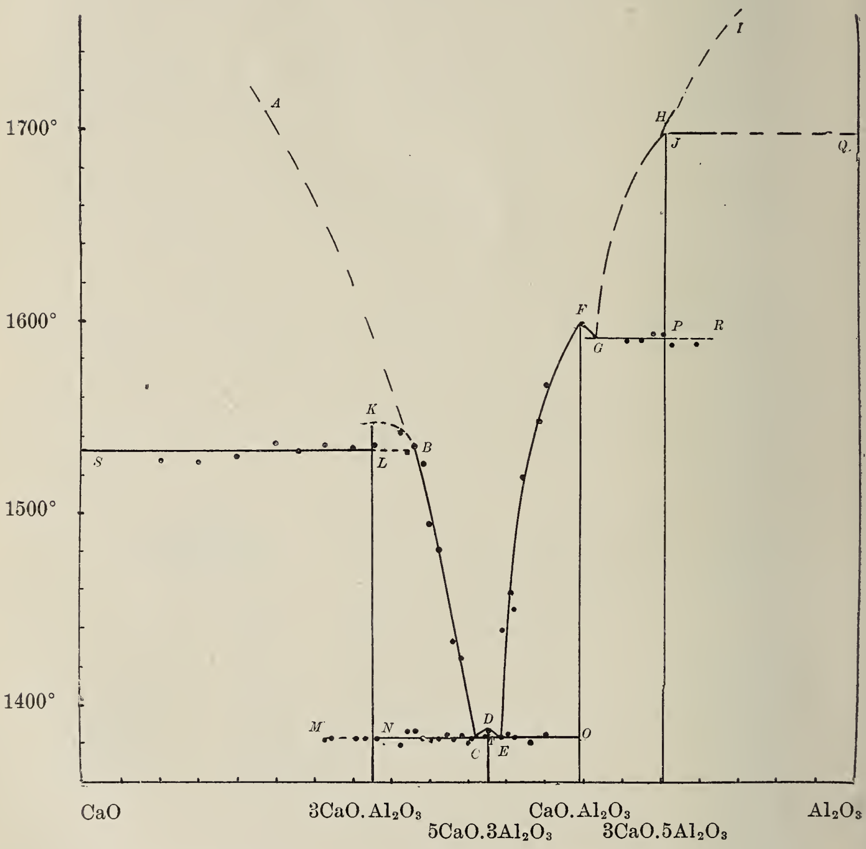
Sillimanite glass.—Sillimanite melts sharply to a very thin liquid which crystallizes with great rapidity. Dropping the crucible of molten sillimanite in water does not cool even a small charge rapidly enough to prevent crystallization. We used the system shown in fig. 5. A is an iridium crucible with a 3^{mm} hole in the bottom. It is supported in the furnace tube, E, on a magnesia ring, B, which is in turn supported by small magnesia rods, C, and the ring, D. The melted charge drops from the tip of the cone directly into the dish of water, F. In this way we obtained a number of globules of glass, with an index of refraction of about 1·625 and a density of 2·54, much lower than sillimanite. When crystallized, either by heat at 1200° or in bombs containing 10 per cent NaCl solution at 350°–400°, the glass yielded only sillimanite. It seems reasonably certain that sillimanite is the stable form and that andalusite and cyanite are formed by crystallization from solution at low temperatures.

Fig. 5.



Lime-Alumina.—It is much more satisfactory to deal with systems in which at least a part of the liquidus can be definitely located with the thermoelement. From about 15 per cent to 70 per cent of alumina, this series can be melted in platinum and all of the eutectics with the exception of $3CaO.5Al_2O_3-Al_2O_3$ can be precisely located by means of the thermoelement. The study of this system with the microscope shows seven phases in addition to the two components. The phases are $CaO.Al_2O_3$, $5CaO.3Al_2O_3$, $3CaO.Al_2O_3$ and an unstable form of both $3CaO.5Al_2O_3$ and $5CaO.3Al_2O_3$. The equilibrium diagram is shown in fig. 6.

Fig. 6.



The approximate melting temperature of lime is not known, except that it melts in the arc. The optical and other properties were given in the lima-silica paper to which reference has been made.

There is no eutectic between lime and the first compound, $3CaO.Al_2O_3$, at 37·78 per cent of alumina. The compound being unstable at its melting point, the liquidus must show a change of direction, but not a minimum. There is, however, an inversion temperature along the line L, where both CaO and $3CaO.Al_2O_3$ separate at the temperature 1531°. For concentrations between L and B the lime which has crystallized combines to form $3CaO.Al_2O_3$. Along the liquidus BC, $3CaO.Al_2O_3$ is the stable phase. In practice, the time factor is a very important one in bringing about these reactions and some lime always becomes surrounded by crystals of the compound, so that the next phase, $5CaO.3Al_2O_3$, also occurs. This renders the eutectic observations along NC more irregular than they would otherwise be and, as the diagram shows, the eutectic, C, occurs as far over as M.

In order to prepare the pure compound $3CaO.Al_2O_3$, it is necessary to bake the charge a long time at about 1400°. This allows diffusion to occur with the elimination of the excess of CaO and $3CaO.5Al_2O_3$ Experimentally, we found that the 37·78 per cent charge, held 21 days at 1400°, was free of the excess phases. Similarly, the compositions 35 per cent, 34 per cent and 32 per cent of Al_2O_3, when merely fused and crystallized, without the long exposure, show $3CaO.Al_2O_3$ with CaO and $5CaO.3Al_2O_3$, but were transformed into CaO and $3CaO.Al_2O_3$ by heating at 1400° for the same length of time. In order to accelerate the reaction, we took the previously fused charges and ground them to a fine powder before starting the heat treatment. Such cases as this are not uncommon in silicate melts and the investigator must bear them constantly in mind or he will be led far astray.

The compound $3CaO.Al_2O_3$ is isotropic, with density 3·038 for the annealed material. It is readily attacked by water, either hot or cold, and dissolves quickly in dilute hydrochloric acid.

The eutectic (C) between $3CaO.Al_2O_3$ and $5CaO.3Al_2O_3$ at 52·22 per cent occurs at 51 per cent Al_2O_3 and melts at a temperature of 1382°.

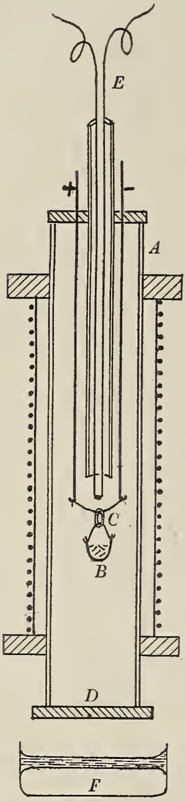
The eutectic (E) between $5CaO.3Al_2O_3$ and $CaO.Al_2O_3$ occurs at about 53 per cent Al_2O_3 and 1382° C.

D is the maximum corresponding to the compound $5CaO.3Al_2O_3$ at 52·22 per cent Al_2O_3, which melts at 1386° C. The maximum is so close to the eutectics, both in composition and temperature, that a precise determination is difficult. It is isotropic, has an index of refraction of about 1·61, and a density of 2·828.

This compound also occurs in an unstable form which is birefracting, but always changes into the isotropic form when given an opportunity to do so.

Between 40 per cent and 60 per cent Al_2O_3 a number of very small irregular heat effects were observed. It was necessary to determine whether or not these changes were in any way related to the stable phases present in this region. Quenching experiments made by removing the charge from the furnace and chilling in water were found to be too slow. Obviously, from a field like E F O, where we have the phase $CaO.Al_2O_3$ in contact with the melt, great speed in cooling is necessary to prevent the whole mass from crystallizing in the presence of the excellent nuclei furnished by the solid phase. Therefore a special device was needed to secure more rapid cooling. The system adopted is shown in fig. 7. Passing through the furnace is a tube, A. Within this tube is placed the element, E. The charge is contained in a small platinum cup, B, suspended by a small porcelain ring from the fine platinum wire, C. This wire is attached to two heavy platinum leads marked + and —. The tube is closed at the bottom by the removable plug, D. F is a dish of mercury with a layer of water above it. In operation the charge is brought to the desired temperature and held for a suitable length of time. The plug D is removed and a strong current passed through the wire C. The current fuses the wire, dropping the charge into the vessel, F. The porcelain ring C prevents the wire of B from sticking to the suspending wire at C.

Fig. 7.



By this method we were able to quench samples of the partly melted charge, obtaining well-formed crystals of the primary phase imbedded in glass. In other words, we were able to bring the charge to room temperature rapidly enough to prevent its changing over. The results of this study are given below: *Time* is the time during which the charge was held at the temperature, *T*, before quenching; *IB*, traces of unstable form of $5CaO.3Al_2O_3$; || present; *tr*, trace.

	Time	T	Glass	CaO	$5CaO.3Al_2O_3$	IB	$3CaO.Al_2O_3$
41% Al_2O_3	30 min.	1544°	||	||	||	||	||
	"	1513°	||	||	||	||	--
	"	1487°	||	||	||	--	--
	60 "	1457°	--	||	||	||	||
	30 "	1454°	--	||	||	||	||
	60 "	1427°	--	||	||	--	||
	90 "	1394°	--	||	||	--	

	Time	T	Glass	$3CaO . Al_2O_3$	IB	$3CaO . Al_2O_3$
44% Al_2O_3	30 min.	1544°	‖	‖	--	--
	"	1513°	‖	‖	--	--
	"	1484°	‖	‖	--	--
	"	1454°	‖	‖	--	--
	"	1425°	‖	‖	--	--
	60 "	1425°	‖	‖	--	--
	"	1394°	--	‖	--	--
	"	1394°	--	‖	--	‖

	Time	T	Glass	IB	$3CaO . Al_2O_3$	$5CaO . 3Al_2O_3$
45% Al_2O_3	30 min.	1535°	‖	‖	--	--
	"	1535°	‖	--	--	--
	"	1530°	‖	‖	--	--
	"	1527°	‖	‖	--	--
	"	1531°	‖	‖	--	--
	"	1520°	‖	‖	‖	--
	"	1520°	‖	‖	‖	--
	"	1520°	‖	‖	‖	--
	"	1520°	‖	‖	‖	--
	"	1506°	‖	‖	‖	--
	"	1506°	‖	‖	‖	--
	"	1598°	‖	‖	‖	--
	"	1491°	‖	--	‖	--
	"	1484°	‖	--	‖	--
	"	1476°	‖	‖	--	--
	"	1458–52	‖	--	--	--
	"	1439°	‖	‖	--	‖
	60 "	1443°	‖	--	‖	--
	"	1423°	‖	--	‖	--
	105 "	1419°	‖	--	‖	--
	60 "	1394°	‖	--	‖	--
	240 "	1513°	--	--	‖	‖
	"	1503°	‖	--	‖	--
47% Al_2O_3	"	1549°	‖	‖	--	--
	60 "	1513°	‖	--	--	--
	30 "	1513°	‖	--	--	--
	"	1484°	‖	--	--	--
	"	1458°	‖	--	‖	tr
	"	1427°	‖	--	‖	--
	"	1394°	--	--	‖	‖
50% Al_2O_3	"	1549°	‖	--	--	tr
	"	1513°	‖	--	--	tr
	"	1484°	‖	--	--	--
	50 "	1456°	‖	--	--	--
	30 "	1427°	‖	--	--	tr
	60 "	1394°	--	--	‖	‖

	Time	T	Glass	IB	$3CaO . Al_2O_3$	$5CaO . 3Al_2O_3$
51% Al_2O_3	60 min.	1404°	--	--	‖	‖
	30 "	1409°	‖	--	‖	‖
	60 "	1420°	‖	--	--	‖
	105 "	1430°	‖	--	--	tr
	60 "	1439°	‖	--	--	tr
	30 "	1454°	‖	--	--	tr
	"	1484°	‖	--	--	tr
	"	1513°	‖	--	--	tr
	60 "	1513°	‖	--	--	--
	"	1544°	‖	--	--	--

	Time	T	Glass	IB	3CaO. Al_2O_3	$5CaO.3Al_2O_3$	$CaO.Al_2O_3$
52.22% Al_2O_3	30 min.	1565°	‖	--	--	--	--
	“	1513°	‖	--	--	--	--
	“	1484°	‖	--	--	--	--
	“	1454°	‖	--	--	--	--
	“	1424°	‖	--	--	‖	tr
	“	1394°	‖	--	--	‖	‖
53% Al_2O_3	“	1544°	‖	--	--	--	--
	“	1513°	‖	--	--	--	--
	“	1484°	‖	--	--	--	--
	“	1454°	‖	--	--	tr	--
	“	1427°	‖	--	--	‖	‖
	60 “	1431°	‖	--	--	‖	‖
	30 “	1385°	--	--	--	‖	‖
55% Al_2O_3	“	1394°	--	--	--	‖	‖
	“	1424°	‖	--	--	--	‖
	“	1458°	‖	--	--	--	‖
	“	1486°	‖	--	--	--	--
	“	1513°	‖	--	--	--	--
	“	1544°	‖	--	--	--	--

	Time	T	Glass	IB	$5CaO.3Al_2O_3$	$CaO.Al_2O_3$
57% Al_2O_3	30 min.	1394°	--	--	‖	‖
	“	1428°	‖	--	‖	‖
	“	1454°	‖	--	--	‖
	“	1484°	‖	--	--	‖
	“	1513°	‖	--	--	‖
	“	1544°	‖	--	tr	tr
60% Al_2O_3	45 “	1544°	‖	‖	--	‖
	30 “	1513°	‖	‖	--	‖
	120 “	1513°	‖	‖	--	‖
	“	1513°	‖	--	--	‖
	“	1454°	‖	--	--	‖
	30 “	1424°	‖	--	‖	‖
	180 “	1424°	--	--	‖	‖
	120 “	1394°	--	--	‖	‖

Examination of this series of quenchings shows that the birefracting phase, which was found to be homogeneous at 52·22 per cent Al_2O_3, is not present as a stable phase. It appears in small amounts (indicated by IB) in certain quenchings and not in others. It usually occurs in mixtures where a large charge is taken from the furnace and air-cooled. It appears in the same charge along with the stable phase, but disappears when the mass is baked at 1300°, passing into the stable form. The heat effects due to this unstable form occur irregularly both as to temperature and time of development. They are destroyed by holding the charge just below NO for a time before making the heating curve.

The spinel analogue $CaO.Al_2O_3$ melts at 1587°. It has a density of 2·981. It is a birefracting crystalline substance, attacked slowly by cold water and readily by hot. The densities of all of these aluminates were determined in dry turpentine at 25° and reduced to water at 25°=1. Hydrochloric acid dissolves all of these compounds.

The eutectic $CaO.Al_2O_3-3CaO.5Al_2O_3$ is located at about 67·5 per cent Al_2O_3. The liquidus falls but slightly from 65 per cent to 67·5 per cent, the temperature of the eutectic being 1580°.

At 75·22 per cent the preparation is homogeneous. The melting point, determined optically, is:

		Millivolts	T
Al_2O_3	75·22	·452 ·455	1710°
CaO	24·78	·452 ·452	

There is a second crystal form of the $3CaO.5Al_2O_3$ compound which shows different optical properties and a specific gravity of 3·05, determined by flotation. It seems probable that the relation of the two is monotropic, though the speed with which this higher form changes into the lower, together with the high temperature, makes quenching experiments unsatisfactory. Crystals of the low form usually show indications of having inverted during cooling, while preparations quenched from above line GP do not. GP is an inversion point, and as it extends to R, indicates that the 75·22 compound is unstable at its melting point. In the iridium furnace, the 75·2 per cent Al_2O_3 preparation seems to melt before the 76·5 per cent. This means either that the $3CaO.5Al_2O_3$ is unstable at its melting point or that the eutectic is so close to the maximum that the necessarily crude method will not determine it. The evidence indicates the former relation and we have adopted it. The 76·5 per cent Al_2O_3 shows free alumina, as do all preparations between this and 100 per cent Al_2O_3.

TABLE II.—Invariant System $CaO+3CaO.Al_2O_3$. (Line S L B, Fig. 6)

Percentage of Al_2O_3	10	15	20	25	28	31·29	35	37·78	41	42	43
Eutectic melts	1526° 28 28 28 28 27 -- --	1524° 26 26 26 26 26 -- --	1530° 30 29 29 29 29 -- --	1536° 35 36 36 36 36 -- --	1531° 30 31 32 32 32 33 34	1535° 35 35 35 35 35 38 37	1534° -- 33 33 34 33 33 35	1535° 35 34 36 33 34 33 --	1543° 42 35 35 35 34 -- --	1529° 31 31 33 33 -- -- --	1535° 34 35 34 34 34 35 --
Mean	1528	1526	1529	1536	1532	1536	1534	1534	1537	1531	1534

TABLE III.—Eutectic $3CaO . Al_2O_3 + 5CaO . 3Al_2O_3$. (Line T N M)

Percentage Al_2O_3	51	50	49	48	47	46	45	44	43	42	41	37·78	35	31·29
Eutectic melts	1383°	1383°	1386°	1386°	1382°	1387°	1385°	1384°	1387°	1384°	1377°	1377°	1374°	1380°
	83	84	80	83	85	85	81	83	86	86	84	77	75	84
	84	71	81	82	82	79	80	82	81	81	76	77	77	80
	83	83	81	74	84	80	81	78	--	--	--	75	--	--
	84	78	90	86	--	76	79	83	--	--	--	--	--	--
	84	81	84	81	--	78	83	79	--	--	--	--	--	--
	--	77	80	84	--	79	--	85	--	--	--	--	--	--
	--	78	--	--	--	76	--	83	--	--	--	--	--	--
	--	77	--	--	--	87	--	--	--	--	--	--	--	--
	--	78	--	--	--	89	--	--	--	--	--	--	--	--
	--	--	--	--	--	85	--	--	--	--	--	--	--	--
	--	--	--	--	--	88	--	--	--	--	--	--	--	--
Mean	1384	1379	1383	1382	1383	1382	1381	1382	1385	1384	1379	1377*	1375*	1381*

* Eutectic points occurring beyond 37·78 composition, due to failure to reach equilibrium.

TABLE IV.—Eutectic $CaO . Al_2O_3 + 5CaO . 3Al_2O_3$. (Line T O)

Percentage of Al_2O_3	60	59	57	56	55	54
Eutectic melts	1384°	1388°	1381°	1388°	1390°	1384°
	----	86	75	82	83	81
	----	83	78	81	80	82
	----	78	78	81	80	82
	----	83	84	81	78	86
	----	77	89	79	83	88
	----	--	79	88	89	80
	----	--	82	--	--	--
	----	--	78	--	--	--
	----	--	79	--	--	--
Mean	1384	1382	1380	1383	1383	1383

TABLE V.—Melting Points.

Percentage of Al_2O_3	60	57	50	46	45	44	43	42	41	37·78	31·29
Melts	1473°	1467°	1458°	1435°	1446°	1430°	1454°	1455°	1426°	1427°	1458°
	75	77	45	39	38	29	36	51	28	23	49
	63	62	53	39	24	28	34	51	21	59	--
	--	58	45	38	30	47	38	49	--	--	--
	--	--	--	39	24	47	36	--	--	--	--
	--	--	--	31	29	40	--	--	--	--	--
	--	--	--	23	27	--	--	--	--	--	--
	--	--	--	20	--	--	--	--	--	--	--
	--	--	--	20	--	--	--	--	--	--	--
	--	--	--	18	--	--	--	--	--	--	--
	--	--	--	16	--	--	--	--	--	--	--
Mean	1470	1466	1450	1429	1431	1437	1440	1452	1425	1436	1454

TABLE VI.—Curve of melting points. (Curve A, B, C, D, E, F, G, H)

Percentage of Al_2O_3	75·22 *	67·5	64·58	60	59	57	56	55	54	53
Component in excess melts	1710°	1581°	1587°	1568°	1537°	1495°	1444°	1458°	1443°	1389°
	----	----	----	66	48	1500	54	63	35	85
	----	----	----	66	50	1499	50	--	37	87
	----	----	----	64	48	98	50	--	33	86
	----	----	----	68	48	--	48	--	34	82
	----	----	----	65	49	--	47	--	38	--
	----	----	----	68	49	--	47	--	40	--
Mean	1710	1581	1587	1566	1547	1498	1449	1461	1437	1386

Percentage of Al_2O_3	52·22	51	49	48	47	46	45	44		
Component in excess melts	1387°	1383°	1429°	1435°	1440°	1480°	1495°	1525°		
	90	83	23	36	40	79	93	24		
	85	84	25	32	37	82	98	25		
	84	83	24	33	36	81	97	--		
	83	84	25	33	--	83	90	--		
	84	84	20	28	--	--	93	--		
	--	--	--	28	--	--	--	--		
	--	--	--	33	--	--	--	--		
	--	--	--	32	--	--	--	--		
Mean	1386	1384	1424	1432	1438	1481	1494	1525		

* Determination in iridium furnace with optical pyrometer.

TABLE VII.—Eutectic $CaO.Al_2O_3 + 3CaO.5Al_2O_3$. (Line G R)

Percentage Al_2O_3	67·5	70	73·22	74·2	75·22	76·5
Eutectic melts	1581°	1582°	1582°	1578°	1577° 1579	1572° 1574 1574
Mean	1581°	1582°	1582°	1578°	1578°	1573°

The Al_2O_3 melts too high for safe determination in the iridium furnace. Apparently, some $3CaO.5Al_2O_3$ crystallizes with the alumina since its optical properties are slightly changed, but we have been able to detect $CaO.Al_2O_3$ in the 95 per cent mixture, so that the range of this solid solution is less than five per cent.

Lime-Magnesia and Magnesia-Alumina.—While the melting temperatures of both of these series lie beyond our present methods, we have made some preliminary fusions in order to ascertain whether or not compounds formed between them. It was necessary to use a furnace made of the purest artificial graphite, the cone being supported on a graphite block which did not form a part of the furnace resistance.

It was found that in all fused mixtures of CaO and MgO the two oxides crystallized out side by side, showing no evidences of combination, from which we conclude that there is no compound between the two. These temperatures are beyond the working range of the iridium furnace. Even with the purest graphite, small amounts of silica will get into the cones, giving a small amount of birefracting material which is identical in all determinable properties with Mg_2SiO_4. This would seem to account for the birefracting material sometimes found when these oxides are fused in the arc. The amount of this birefracting substance was independent of the nominal composition.

The location of the eutectic was rendered uncertain because of the attack on the lime by the graphite.

Magnesia-Alumina.—This series, melted in graphite, gave one well-formed compound, $MgO.Al_2O_3$, similar to the lime-alumina series. There was no other compound formed. Between 0 per cent and 71·6 per cent Al_2O_3, the solid phases are MgO and $MgO.Al_2O_3$. Between 71·6 per cent Al_2O_3 and 100 per cent Al_2O_3, $MgO.Al_2O_3$ and Al_2O_3 are the solid phases. The melting temperature of the $MgO-MgO.Al_2O_3$ eutectic is at about 1950°.

These last two series are given only for the purpose of guidance in calculating the possible effect of small amounts of magnesia, which in commercial work are always present in the lime-alumina-silica mixtures. In time, some one may devise a furnace and containing vessel which will allow their more precise examination.

The results of the present thermal study may be summarized as follows:

1. There is but one compound (Al_2SiO_5) of alumina and silica stable in contact with the melt. This is the mineral sillimanite. The two minerals andalusite and cyanite pass slowly into sillimanite on being heated above 1300° C.

2. There are four definite compounds of lime with alumina, namely, $3CaO.Al_2O_3$; $5CaO.3Al_2O_3$, melting point 1387° C.; $CaO.Al_2O_3$, melting point 1587° C.; $3CaO.5Al_2O_3$.

3. $3CaO.Al_2O_3$ and $3CaO.5Al_2O_3$ have no true melting point, but the former will be completely melted at about 1550° and the latter at about 1725° C.

4. Two of these compounds, $5CaO.3Al_2O_3$ and $3CaO.5Al_2O_3$, have an unstable form each, while $3CaO.Al_2O_3$, and probably $3CaO.5Al_2O_3$, are unstable at the melting point, i. e., do not produce a maximum on the liquidus.

5. Of these aluminates it seems probable that only $3CaO.Al_2O_3$ will occur in portland cement.

6. There is one compound, $MgO.Al_2O_3$, between magnesia and alumina.

7. There is reason to believe that the system MgO–CaO is a eutectic series with no compound and little if any solid solution. The temperature range is too high for satisfactory investigation.

Having established the nature of the binary systems, experimental study of the ternary system $CaO-Al_2O_3-SiO_2$ is now under way.

Optical Study; by FRED. EUGENE WRIGHT.

In the foregoing pages the general problem of the lime-alumina series has been considered in detail, the different compounds in the series have been described and their stability relations at different temperatures discussed; in brief, all data, chemical, thermal and optical, which bear on the problem, have been used, and the conclusions reached are based on the entire evidence at hand. In this treatment of the problem, its physico-chemical aspects have been especially emphasized because the established generalizations of physical chemistry best explain and define the limits in the relations of the combining minerals, and such data are of fundamental significance in the general study of rock and ore genesis. A restatement of the entire lime-alumina problem from the optical standpoint with the thermal and chemical data as confirmatory evidence, although possible, is, therefore, deemed unnecessary, and in the following pages only the detailed optical description of the different components of this series will be given, followed by a brief account of the character, significance and interrelation of the different kinds of experimental evidence which require to be brought to bear upon such problems of petrogenesis for their effective solution.

Calcium Oxide.—Crystals of this substance were not prepared especially for this investigation, since its optic properties have been described in detail in a former paper.* Free lime crystallizes readily in the isometric system, is isotropic and occurs in the different preparations of this series in the form of rounded grains. A remeasurement of the refractive index by the immersion method in a liquid consisting of methylene iodide, arsenic bromide and arsenic sulphide, was made, and the index found to be $1{\cdot}832 \pm {\cdot}005$. The high probable error is partly due to the lack of distinctness of the phenomena observed and to the slight attack of the lime by the solution itself.

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* This Journal (4), xxii, 294, 1906.

The most interesting fact with respect to the lime which has come to light in the course of this investigation is the evident growth of the grains at temperatures above 1300°. Fine impalpable powder resulting from the calcination of calcite was heated for a week in the electric resistance furnace at 1300°–1400° and found at the end of that time to consist of rounded grains of lime measuring as high as ·01–·02^{mm} in diameter in place of the submicroscopic material which went into the furnace. This temperature is 1000° or more below the melting temperature of crystallized calcium oxide, and yet at ordinary atmospheric pressure and in the dry state crystals of calcium oxide grow rapidly at 1400° and resemble in all respects those formed out of melts of different compositions. This principle of causing crystal growth many degrees below the melting point and in the dry state is being applied constantly in this laboratory to render fine microscopic preparations suitable for optical examination. Experience thus far gained has shown that not all compounds grow with equal rapidity under these conditions, and in fact free alumina seems to be little affected by this treatment. The growth of calcium oxide crystals under these conditions is, however, definitely established, and is an important fact to be taken into consideration in connection with crystal formation and growth.

The $3CaO.Al_2O_3$ *compound:* *CaO 62·22,* Al_2O_3 *37·78.*—Preparations of this composition have never been obtained perfectly homogeneous and free from grains of free lime and also of the lower refracting $3CaO.5Al_2O_3$ compound. The amounts of the latter, however, are not large and their presence has been shown to be due to dissociation. Optically this compound is simple in its properties. It crystallizes in the isometric system and exhibits no pronounced cleavage. Indications of cleavage after (111) or (110) were observed here and there, but only imperfectly developed. The fracture is conchoidal; the hardness is about 6. Although no separate crystals for goniometric measurement could be obtained, the frequent hexagonal and rectangular outlines of the grains in the thin section indicate the rhombic dodecahedron (110) or octahedron as the predominating form. The grains are colorless, of glassy luster, and isotropic, with refractive index $n_{Na}=1·710\pm·001$ measured on the Abbe total refractometer. Occasionally faint gray interference colors were observed on certain grains and were evidently due to strain. No definite arrangement of inclusions or zonal growth was noticeable, even on the largest grains, measuring 0·1^{mm} in diameter.

The $5CaO.3Al_2O_3$ *compound:* *CaO 47·78,* Al_2O_3 *52·22.*—Separate crystals of this compound were not obtained and no distinct cleavage was observed, either in the crystalline powder or in the thin sections of the different crystallized melts. In the thin section, however, minute inclusions, apparently air cavities, are often arranged in systems of parallel lines intersecting at different angles and occasionally there appears a tendency to fracture along these lines, although it is not sufficiently pronounced to be called even poor cleavage. The sections are completely isotropic in all positions and the crystal system is therefore isometric. The melts are frequently colored especially in shades of yellow or brown, the color being probably due to contamination with platinum from the crucibles in which the melts were made. The luster is vitreous and the fracture conchoidal and often interrupted. The hardness is about 5. The refractive index, measured on the total refractometer, was found to be $n_{Na}=1·608\pm·002$. The refractive indices of crystals from preparations slightly different in composition from the $5CaO.3Al_2O_3$ compound were measured with the following results:

CaO 43, Al_2O_3 57 .... $n_{Na}=1·61\pm1·003$
CaO 49, Al_2O_3 51 .... $n_{Na}=1·611\pm·003$
CaO 51, Al_2O_3 49 .... $n_{Na}=1·611\pm·003$

None of these measurements were good, and in view of the lack of homogeneity of preparations adjacent to the $5CaO.3Al_2O_3$ compound in chemical composition, it is evident that solid solution in this compound is not pronounced, but is, in fact, extremely limited if present at all.

The refractive index of the glass of the composition of this compound is about 1·662; it is interesting to note that in this compound crystallization means molecular rarefaction and not molecular condensation, which is usually the case.

The unstable $5CaO.3Al_2O_3$ *compound:* CaO *47·78,* Al_2O_3 *52·22.*—The crystallographic development is much less favorable for optical examination than that of other members of the lime-alumina series. The very fact of its unstable character precludes crystal growth for a long period of time under any but very special conditions, and as a result the material available for investigation is finely crystalline and usually intricately intergrown, either as radial spherulites or in aggregates of overlapping and often roughly parallel fibers. The optic properties which can be obtained with such material are few and less accurate than those from well-developed crystals. The crystal habit is fibrous to prismatic; cleavage if present is parallel with fiber direction but not perfect. The luster is vitreous and the color usually green and due possibly to slight admixture of platinum from the crucible. The hardness is about 5. The refractive indices were measured by the immersion method and found to be $\alpha=1·687\pm·002$, $\gamma=1·692\pm·002$. The birefringence is not strong and only rarely were interference colors as high as yellow red of the first order observed, and even then the color appeared slightly abnormal, due evidently to the effect of overlapping fibers. The optic axial angle is large and the optical character apparently negative, but not easy to determine satisfactorily because of the aggregate effect of superposed fibers. The plane of the optic axes is parallel with the elongation of the fibers. The fibers show parallel extinction with the ellipsoidal axis $\mathfrak{c}$ parallel with the direction of elongation. Some of the more deeply colored grains are pleochroic with $\mathfrak{a}$=blue green, $\mathfrak{c}$=olive green. Absorption $\mathfrak{a} > \mathfrak{c}$.

These properties indicate that this compound is probably orthorhombic in crystal system. Compared with the other members of the series, its chief characteristics are the refractive indices about 1·69, weak birefringence and tendency to fibrous development.

Evidence of solid solution of other compounds in this form was looked for but was not decisive. In a preparation containing 50 per cent Al_2O_3 the unstable form was observed and there appeared to have slightly higher refractive indices, but the differences were only in the third decimal place and practically within the errors of observation.

The $CaO.Al_2O_3$ *compound:* CaO *35·44,* Al_2O_3 *64·56.*—No single crystals of this compound were obtained and the determination of the crystal system rests entirely on the optical data. In one preparation of this composition from the iridium furnace elongated needles and prisms were observed, but on examination were found to be not single crystals but intricately twinned individuals with only indications of poorly developed crystal faces.

Twinning is a characteristic feature of this compound and is especially noticeable on sections nearly normal to the acute bisectrix. Such sections are intricately divided into a hexagonal meshwork of interlocking sextants which extinguish in different positions. On such sextants the plane of the optic axes was found to be usually normal to an edge. On plates cut at an angle with the acute bisectrix, polysynthetic twinning lamellæ were often observed and in aspect were not unlike plagioclase lamellæ. The general development of the material from the crystallized melts is prismatic with a tendency toward fibrous character. Cleavage is occasionally indicated and is then parallel with the direction of elongation and apparently prismatic or pinacoidal in character. The fibers extinguish often parallel with their elongation, the ellipsoidal axes $\mathfrak{a}$ being then parallel with the long direction; but in many sections the extinction is not parallel with the prismatic axis and makes large angles with the same.

The crystalline aggregates are colorless and vitreous in luster. The hardness is about 6·5. The refractive indices α and γ were determined on the Abbe total refractometer, while β was measured by the immersion method. $\gamma = 1{\cdot}661 \pm {\cdot}002$; $\beta = 1{\cdot}654 \pm {\cdot}003$; $\alpha = 1{\cdot}641 \pm {\cdot}002$. The birefringence is fairly strong and interference colors of the first to third orders are common. The optic axial angle was measured by use of the double screw micrometer ocular on sections showing an optic axis in the field of vision. Owing to the frequent twinning some difficulty was experienced in finding suitable sections and the values obtained also varied slightly in consequence. Five fairly satisfactory measurements were made and the average value $2V = 36° \pm 4°$ obtained. Dispersion of the optic axes is very slight and ordinarily not noticeable. On one section the relations seemed to be $2V_\rho > 2V_v$. Occasionally a section with apparently smaller 2V than usual was observed, almost uniaxial, but this was possibly due to the effect of overlapping twinning.

These data indicate that the crystal system of the compound $CaO.Al_2O_3$ is either monoclinic or triclinic and probably the former. Unfortunately, no well-developed crystals were obtainable and a more definite statement in regard to the symmetry relations is not possible.

The $3CaO.5Al_2O_3$ *compound:* CaO *24·78,* Al_2O_3 *75·22.*—No separate crystals of this compound were obtained and the evidence as to its crystal system, whether tetragonal or hexagonal, is not satisfactory. The grains are rounded and range from ·02 to ·05^{mm} in diameter. Basal sections are usually without definite outline, though occasionally there is a tendency toward quadratic outline, and it is possible that the crystal system is tetragonal. No distinct indications of cleavage were observed. Rarely rhomb-shaped to square grains were noted which extinguish parallel with the diagonals and may indicate poor pyramidal cleavage, or if hexagonal, rhombohedral cleavage, but such grains were rare, and if cleavage be present it is imperfect. The luster is vitreous and the hardness about 6·5. The refractive indices were determined by the immersion method: $\omega = 1{\cdot}617 \pm {\cdot}002$; $\epsilon = 1{\cdot}651 \pm {\cdot}002$. On a section parallel with principal axis the birefringence was measured roughly under the microscope and the value $\gamma - \alpha = {\cdot}032$ obtained. The birefringence is, therefore, fairly strong and the interference colors, even in minute grains, are of the first and second orders. In convergent polarized light a normal uniaxial, optically positive interference figure was observed on basal sections. The interference cross is well marked and on thicker sections the inner edge of the first colored interference ring is visible on the margin of the microscope field. In some of the sections a slight opening of the interference cross was observed as though the substance were biaxial with small 2E, but so many of the sections were perfectly uniaxial that there is little doubt of the uniaxial character of the substance. This compound is readily distinguished from the $CaO.Al_2O_3$ compound by its interference figure, optical character and constant refractive index, $\omega = 1{\cdot}617$. On practically every basal section thin threadlike inclusions of a higher refracting, weakly birefracting to isotropic substance, were observed and although small in actual quantity they are nevertheless present and may be free Al_2O_3 or the unstable $3CaO.5Al_2O_3$ compound. They are too fine for satisfactory identification by optical methods.

In several of the preparations the crystallographic habit of the compound was entirely different from the small granular type. The individuals were elongated, lath-shaped and intricately intergrown and resembled in aspect γCa_2SiO_4 after inversion from the β-form.* The optic properties, refractive indices, birefringence, uniaxial optical character, proved to be identical with the normal $3CaO.5Al_2O_3$ compound and the peculiar appearance is due in fact to inversion from a high unstable form, just as in the case of calcium orthosilicate.

The unstable $3CaO.5Al_2O_3$ compound: CaO 24·78, Al_2O_3 75·22.—This compound was obtained only after considerable experimentation with preparations in the iridium furnace. Its presence was surmised first from the difference in crystallographic habit of different preparations of the optically positive form of this composition. In no case was it obtained in pure state but invariably showed more or less alteration to the optically positive form, and could not therefore be used for density determinations.

No crystals of this phase were obtained and the determination of its crystal system rests entirely on the optical evidence. The crystalline melts are colorless and often porcelain-like in appearance. Here and there minute cleavage faces of lath-shaped individuals glisten in strong light. On the whole, the melts were well crystallized, some of the grains under the microscope measuring as much as $\cdot 5^{mm}$ in length. The crystals are usually prismatic in habit and show under the microscope fairly well-marked prismatic cleavage. Their luster is vitreous and hardness about 5·5 to 6. The refractive indices were measured by the immersion method $\gamma = 1{\cdot}674 \pm {\cdot}002$, $\beta = 1{\cdot}671 \pm {\cdot}002$; $\alpha = 1{\cdot}662 \pm {\cdot}002$. A direct determination of the birefringence was made and $\gamma - \alpha$ found to be approximately ·013. The interference colors in ordinary powder sections rarely exceed the second order blue and are usually gray to

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* This Journal (4), xxii, 296, 1906.

yellow of the first order. The optic axial angle was measured by the double screw micrometer ocular 2V = 35° ± 5°. This value is the average of seven different measurements and part of the large probable error is due to the strong axial dispersion, which is pronounced with $2V_\rho > 2V_v$. The attempt was made to determine the angular amount of this dispersion, but the axial figures observed were not sharp enough for precise work and only the general statement can be made that $2V_\rho$ is several degrees larger at least than $2E_v$. The optical character is negative. The grains extinguish parallel with the prismatic cleavage. The ellipsoidal axis $\mathfrak{a}$, and with it the plane of the optic axis, is parallel with the direction of prismatic elongation of the crystals.

The alteration to the optically positive form is clearly marked in the powder. It proceeds from the surface of the grains and works toward the center along the cleavage cracks and occasional transverse cracks, so that as it proceeds the original substance is replaced by a fine meshwork of the optically positive form. The alteration is accompanied by a slight expansion in volume, about 2 per cent judging from the refractive indices, and this in turn tends to facilitate further change by producing further cleavage cracks and causing the crystal to break down entirely. The resulting product of change resembles γ-orthosilicate in appearance and this fact suggested the existence of this probably unstable phase of the $3CaO.5Al_2O_3$ compound.

The above optical data indicate that this compound is in all probability orthorhombic in symmetry. Its chief characteristics are refractive indices about 1·67, medium birefringence, small negative optic axial angle with strong axial dispersion, the plane of the optic axes and the ellipsoidal axis $\mathfrak{a}$ lying parallel with the prismatic cleavage direction of elongation.

Aluminum oxide: Artificial corundum.—This substance melts at an exceedingly high temperature, and in the present series of experiments no special attempt was made to procure measurable crystals. The optic properties were determined on a fine-grained preparation prepared by heating fine impalpable precipitated alumina in the iridium furnace to about 2100°. The crystal grains thus formed are less than $\cdot05^{mm}$ in diameter and of rounded outline. No definite crystal outlines nor cleavage cracks were observed. Air cavities and minute bubbles are characteristic and abundant. The hardness is 9. The refractive indices were determined by the immersion method, $\omega = 1{\cdot}768 \pm {\cdot}003$, $\epsilon = 1{\cdot}760 \pm {\cdot}003$. The birefringence was found to be roughly ·009 on a small section parallel with the principal axis.

In convergent light a faint optically negative, uniaxial interference figure was observed. In short, the optical characteristics of artificial corundum were, so far as determined, practically identical with those of the natural mineral.

Silicium oxide.—In the paper on the lime-silica series,* the thermal and optical behavior of silica at high temperatures was described. Recent work on the silica problem, at low temperatures, has shown it to be much more complicated than was at first supposed. In fact several phases have now been found to occur in that region which were not disclosed by the first investigation. The problem as a whole is not simple and has not yet been satisfactorily solved, so that in the following paragraphs only a report of progress can be made. Apparently six distinct phases occur: α-quartz, β-quartz, α-tridymite, β-tridymite, α-cristobalite, and β-cristobalite. These will be considered in the order named.

α-quartz, or simply quartz, is the ordinary quartz of mineralogists, and requires no further mention. On heating to 575° it passes into β-quartz, which is also hexagonal but trapezohedral-hemihedral in its symmetry relations and in other respects slightly different from α-quartz. The change at 575° is reversible and is exceedingly sensitive to minute temperature variations, a rise or fall of 1/10° at the inversion temperature being sufficient to cause the inversion. These relations have been described in detail and the literature references given in a recent paper in this Journal. †

Tridymite (α-tridymite) occurs in nature in flakes of hexagonal outline. It has been made artificially by several different methods but in practically every case in the presence of a flux.‡ At ordinary temperatures tridymite is intricately twinned, biaxial and apparently orthorhombic in symmetry (pseudo-hexagonal). On heating, the crystals become uniaxial at about 130°,§ and the complicated twinning disappears; the expansion coefficient also changes abruptly at this temperature.‖ On cooling the reverse process takes place slowly and the change is therefore enantiotropic. This inversion of α- to β-tridymite occurs without evidence of great strain or fracturing of the crystals and it is probable that the specific volumes of the two phases are nearly equal. The fact that natural tridymite crystals are hexagonal with respect to outline and orthorhombic in optic properties, while at 130° they invert to a truly hexagonal substance, indicates that in all probability such hexagonal plates

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[*] Day, Shepherd and Wright, loc. cit.

[†] Quartz as a Geologic Thermometer, this Journal (4), xxvii, 421–447, 1909.

[‡] Literature references cited in Hintze, Mineralogie I, 1459–1462.

[§] Mallard, Bull. Soc. Min., xiii, 169, 1890.

[‖] Le Chatelier, Compt. Rendus, cxi, 123, 1890.

were actually formed above 130°.—At ordinary temperatures tridymite, having inverted in the solid state, is intricately twinned and intergrown, and its optical examination is not as a rule satisfactory, especially on artificial crystals. The birefringence is weak and the average refractive index about 1·477.*

Crystal aggregates formed out of pure melts of SiO_2 or from SiO_2 glass or by inversion of quartz heated to a high temperature, show the above properties except that the refractive index is slightly higher, about 1·484±·003 instead of 1·477. In the description of the tridymite from the lime-silica series, the writer noted this higher refractive index but was unable to account for it. Through the courtesy of Professor Lacroix of Paris, however, to whom specimens of the artificial crystals had been sent, this difference can now be explained. Professor Lacroix, after examination of the material, pronounced it to be in all probability cristobalite, and not tridymite, and subsequent examinations here have confirmed Professor Lacroix's determinations. Cristobalite has been found in nature only rarely, and then usually together with tridymite. Its crystals are octahedral in habit, but, like tridymite, are intricately twinned and very weakly birefracting, so that the optical examination is not satisfactory. Its refractive index is slightly higher than that of tridymite, about 1·49.† The optical behavior of cristobalite was first studied by Mallard,‡ who found that at about 175° the crystals became abruptly isotropic, and remain so at higher temperatures. On cooling the reverse process takes place, β-cristobalite changing back to the a form abruptly, the minute birefracting patches flashing up throughout the entire slide as the inversion temperature is reached. The volume change on this inversion is apparently very slight. The fact that this change is reversible and that natural crystals of cristobalite are octahedral in habit indicates that they were in all probability formed above 175°, the inversion temperature.

In the irregular crystalline aggregates obtained in laboratory preparations, tridymite and cristobalite can best be distinguished by heating in the thermal microscope. At about 130° tridymite becomes uniaxial and remains so at higher temperatures, while in cristobalite no change occurs until about 175°, when the interference colors disappear completely, the material becoming isotropic and remaining so at higher temperatures. The refractive index of tridymite (1·477) is slightly lower than that of cristobalite (about 1·484), but the difference is not great, and ordinarily would not, perhaps, be relied on to distinguish the two in very fine powder.

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* Mallard, Bull. Soc. Min., xiii, 169, 1890.
† Gaubert, Bull. Soc. Min., xxvii, 244, 1904.
‡ Bull. Soc. Min., xiii, 175, 1890.

On heating crystal aggregates obtained from the SiO_2 melts, also from SiO_2 glass and from inverted quartz powder, it was observed that at about 175°, or slightly higher, they become isotropic and remained so at still higher temperatures. This behavior proved them to be cristobalite and not tridymite, as had been heretofore supposed.

Several preliminary tests of the heat change involved in this immersion have been made and found to be clearly marked. The investigation of the stability relations between the crystal quartz, tridymite and cristobalite has not yet been completed, and need not therefore be discussed at this point.

Al_2SiO_5 : Sillimanite ; Al_2O_3 62·85 per cent, SiO_2 37·15 per cent.—This compound crystallizes from the melt with great rapidity on cooling, and as a result the preparations available for the optical work are in general too fine-grained for accurate determination. The crystallites are fibrous and lath-shaped in habit, and, like the natural mineral sillimanite, are often in close parallel groups. The optical effect is, therefore, usually that of an aggregate rather than of a single individual. End views of the fiber bundles show that each lath is prismatic in shape with a prism angle of approximately 90°. In the center of nearly every section a minute inclusion is present, often in the shape of a cross, the arms of which are parallel with the sides. In this respect the sections resemble in a way the chiastolite variety of andalusite. The end sections are weakly birefracting and extinguish parallel with the diagonals. The refractive indices, which were measured by the immersion method, are noticeably lower than those of pure natural sillimanite, a fact for which no explanation has yet been found. $\alpha = 1·638 \pm ·003$; $\beta = 1·642 \pm ·003$; $\gamma = 1·653 \pm ·003$. Direct measurements of the birefringence were made and averaged roughly $\gamma - \alpha$ about ·014, but they were not satisfactory owing to the fibrous character of the material and consequent lack of transparency for good thickness measurements. For the same reason the optic axial angle could not be measured satisfactorily. Judging by its general appearance, 2E lies between about 40° and 75°, but unfortunately it was not possible to obtain a more definite value with the material at hand. The optical character is positive, and the acute bisectrix $\mathfrak{c}$ lies in the direction of elongation of the fibers. On one preparation of the composition Al_2O_3 60, SiO_2 40, the crystallization was somewhat coarser, and there the optical axial angle was measured with the double screw micrometer ocular and the value $2V = 45° \pm 4°$ obtained. Dispersion of the optic axes was not observed, and if present is slight. In this preparation well-marked pinacoidal cleavage was also observed parallel with the plane of the optic axes. The same cleavage is characteristic of natural sillimanite.

In every preparation of sillimanite examined, there was present between the sillimanite fibers an isotropic substance of much lower refractive index, about 1·530. This same subtance appears in other preparations of the alumina-silica series, and is probably glass, since its refractive index n, about 1·525–1·530, agrees with that of sillimanite glass obtained by extremely rapid quenching of the melt from the iridium furnace. Sillimanite crystallizes with great rapidity, but its melting point is high and probably in the iridium furnace preparations, where comparatively rapid cooling goes on throughout the region of rapid crystallization for this silicate, not enough time was given for the entire melt to crystallize out, and small threads of glass are included between the crystallized fibers and laths. If the refractive indices be used as a criterion, crystallization in sillimanite means high molecular condensation, and, as a result, numerous air spaces and cavities appear in the crystallized mass.

The presence of glass and minute elongated air cavities tended to render the optical tests for homogeneity in preparations adjacent to the pure compound uncertain. No free corundum was observed in the preparation SiO_2 35, Al_2O_3 65, but it was readily detected in the preparation SiO_2 30, Al_2O_3 70. So far as the optical evidence goes, solid solution of Al_2O_3 in Al_2SiO_5 may extend to the composition SiO_2 35, Al_2O_3 65, but not to SiO_2 30, Al_2O_3 70. The refractive indices of the sillimanite fibers in the preparation SiO_2 35, Al_2O_3 65, were practically identical with those of the pure compound, but measurements of a high degree of accuracy were not possible, because of the character of the material.

Magnesium Oxide: Artificial periclase.—Preparations of this oxide were made both by crystallizing the pure melt in the electric arc and also from fluxes of magnesium chloride and silica. The crystals from the latter were well developed and octahedral in habit with occasional small cube faces. From the melt they occur as rounded grains often irregular in shape and without polyhedral outline in aggregated clusters and masses. Cubic cleavage is well marked even on the grains and was produced directly on the octahedral crystals. Octahedral cleavage if present is not distinct. The crystals and grains are colorless and perfectly isotropic with refractive index 1·734 ± ·002, determined by immersion method. The hardness is about 6, apparently slightly above 6, since the grains appeared to scratch adularia very slightly. Solid solution in periclase is not great if it occurs at all. In a preparation MgO 90, CaO 10, free lime was present in the usual rounded grains, while the refractive index of the periclase was practically unchanged.

$MgO.Al_2O_3$: Artificial spinel, MgO 38·32, Al_2O_3 71·68.—Crystals of this compound were obtained by direct crystallization from the pure melt in the electric arc furnace. The resulting crystals were minute but sharply developed octahedrons, clear and transparent, colorless and splendent in luster. In the aggregate they occur frequently with approximately parallel orientation in rows and clusters, not unlike skeleton salt crystals in appearance.—Evidence of twinning after the usual spinel law was sought for but without decisive results, chiefly because of the fineness of the material. Cleavage if present is imperfect and not well marked in the powdered material. The hardness is about 8. The refractive index, $n = 1·723 \pm ·002$ (determined by immersion method), is slightly higher than that of spinel ordinarily, although spinels of even higher refractive index have been observed. Under the microscope the grains and crystals are isotropic and without abnormal interference phenomena.

Evidence of slight solid solution, both with alumina and magnesia, was indicated by the slightly lower refractive index of the spinel crystals from preparations adjacent to the true compound in composition (Al_2O_3 75, MgO 25 and Al_2O_3 60, MgO 40). Satisfactory tests for homogeneity of adjacent preparations were, however, not possible because of the presence of small quantities of a birefracting substance of refractive index about 1·66 and medium birefringence, but too fine for definite identification. This substance occurred in different members of the alumina-magnesia series and together with both periclase and spinel, and is therefore possibly due to impurity from the carbon in which the preparations were melted.

Solid solution over a long range in the above series does not exist. This is evident not only from the thermal work but also from the optical tests for homogeneity and the determination of the optical constants especially of refractive indices of the components of preparations intermediate in composition between the compounds. The refractive indices of the compound $5CaO.3Al_2O_3$ appear slightly higher in preparations on either side of the true compound, and this might be taken to indicate very limited solid solution, but the observed differences are practically within the limit of possible observational error, and too much stress cannot be placed on the evidence. The same holds true for the optically positive compound $3CaO.5Al_2O_3$, and also the optically negative form of the same composition, for which the refractive index γ appeared very slightly lower in the preparation CaO 25·78, Al_2O_3 74·22, than in the true compound, but the difference was within the possible error limit and the evidence is not definite. The optically positive uniaxial $3CaO.5Al_2O_3$ compound appears noticeably biaxial in certain sections, and this may have been due to solid solution, but if so the extent of solid solution is not great. The unstable $5CaO.3Al_2O_3$ compound and also the $CaO.Al_2O_3$ compound showed slight variations in the optic axial angle which might be ascribed to the effects of solid solution, but in such instances the quality of the material was not favorable for decisive optical tests. Evidence of slight solid solution of MgO and also Al_2O_3 in spinel was indicated by refractive index determinations on preparations adjacent to spinel in composition.—CaO may also take up small amounts of MgO in solid solution, so far as could be ascertained by the microscopic examination.

The geologic significance of these binary series.—In the preceding pages the optic properties of the several different compounds of the different series have been cited in detail and this evidence, in turn, has been used in general presentation of this problem in the first part of this paper. The bearing of such data, however, on geologic work has not been mentioned, and it may be of interest to outline in a few paragraphs the particular kinds and scope of evidence which the different methods, chemical, physical and optical, furnish in a problem like the present one, which in turn is only a detail of still larger problems whose ultimate solution will be of fundamental importance in the consideration of questions of rock and ore genesis and allied phases of geologic inquiry.

In the general attack upon complex problems of this nature, experience has shown that exact and definite data along three distinct lines of evidence, chemical, thermal, and optical, are necessary and usually adequate for their satisfactory solution. No one of these three lines is of itself sufficient for the complete solution of the problem, nor yet are they entirely independent of each other. Although supplementary to a certain extent, they overlap in their spheres of application, so that the results obtained by one method can be and usually are confirmed by those of a second, thus strengthening the foundation of fact on which subsequent reasoning is based.—By careful chemical work the purity of the preparations is insured; by thermal measurements the relative energy content of the different preparations at different temperatures is investigated; while by optical methods the number of compounds in a given preparation is determined (mineral composition), their optical constants ascertained and their special relation to each other recognized (texture).—To present more clearly the scope of these three fundamental lines of evidence which are essential for the solution of problems of this type, it will be well to consider each separately first, and then to indicate briefly wherein they overlap and are mutually confirmatory.

Chemical data.—Modern research has shown that as a rule rock minerals are not single, simple compounds but complex mix-crystals containing various other mineral compounds in solid solution. The investigation of such minerals and their relations in rocks can only be satisfactorily carried on, therefore, after the characteristics of the simple compounds have been ascertained, as well as the extent and the effect of the by-mixture. In the general investigation of problems of such wide scope it is necessary to begin with the simplest conditions, and after these have been thoroughly mastered, to work up to the more complex. From a physico-chemical standpoint, rocks are as a rule complex systems, too complex in fact to be treated satisfactorily until the simple integral systems of which they are made up have been studied in detail. The present lime-alumina series is only one of a number of two-component systems which mark the limits of larger three-component systems, and these in turn lead to still larger systems. Such systems eventually become exceedingly complex, and the only hope the observer has of mastering them is to begin with the simplest cases first and then with the experience thus gained to proceed step by step to the more complex. The simplest systems are the two-component systems, as the lime-alumina series, and the chief function of the chemical work is to make up preparations of definite composition and to guarantee their purity throughout the investigation. Natural rock minerals are almost never rigidly pure, in the sense of definite and invariable chemical composition, and yet their investigation from the standpoint of laboratory synthesis requires that at first only chemically pure preparations of definite composition be taken, and the properties of these determined accurately; later the actual minerals can be reproduced artificially and the effect of solid solution of different substances in different proportions can be studied and definite information obtained. Impurities in solid solution tend only to veil the true relations of the compound itself, and for the observer to allow such a variable factor as impurity into the investigation at the very outset would operate not only to increase the difficulties but also to decrease the clean-cut aspect of the problem and the laws underlying it.

Other data which are of a physico-chemical nature, such as questions of relative solubility, concentration and the like, may properly be considered in a later paragraph.

Thermal data.—The object of experimentation along these lines is not only to reproduce rock-making minerals artificially, but especially to study the conditions of their formation and the temperature and pressure ranges over which they are stable. From such data general laws of equilibrium can be deduced and tested and then applied directly to the rocks themselves, which in effect are the end-products of physico-chemical systems. In the case of igneous and metamorphic rocks we have to deal with chemical systems that have been subjected to certain physical conditions which, in turn, have left their imprint or seal on the end-product or rock now accessible to the geologist. It is the task of the geologist to decipher this seal as he finds it expressed in terms of mineral composition and texture, and from it to infer the conditions of original formation. The actual processes of formation have not been and in general cannot be witnessed by him, and he must base his conclusions on the existing evidence, weighed in the light of his own experience. Such evidence is in part geologic, but in no small degree experimental, and the more evidence of an experimental nature there is at hand, the more confident is he of his conclusions. Exact thermal data especially are lacking, but are of fundamental significance, since they indicate limits at which the energy content of the system changes abruptly; any change of this kind, such as the melting and inversion temperatures of compounds, or eutectic temperatures of mixtures, is most important, since it is the outward expression of a shift of the equilibrium of the system, as a result of which profound changes may occur. What before was stable may become unstable, and vice versa; a rearrangement of forces accompanies the change in energy content and new stability relations are at once established.

Under normal conditions, therefore, thermal measurements are adapted to indicate the relative energy content of any preparation at different temperatures. But by so doing they indicate the presence of different compounds in a series and establish temperature ranges over which these compounds and mixtures of the same are stable.

Optical data.—The microscopic examination of the preparations, at ordinary room temperatures and after the changes have taken place, does not of itself directly prove an energy change in the system. In the thermal microscope such changes can be followed in their effect on the optical properties (melting down of crystal plates, abrupt changes in birefringence, optic axial angle, and the like), but such evidence is used ordinarily only to confirm the purely thermal data. The purpose of the microscopic investigation is primarily to determine the compounds present in any preparation (composition, with special reference to homogeneity and crystallization), to study the relation of the different components to each other (texture) and to establish by measurement the degree of departure of natural minerals with their varying admixtures, from the chemically pure ultimate types. By the microscopic examination of preparations of different composition in a given series, the number of compounds in the series can be ascertained, the different phases in which any given compound appears, and also the extent to which any particular compound takes up an adjacent compound in solid solution. The exact determination of the optic constants of the different members of the series furnishes, morever, data which permit any one of them to be recognized, even in the presence of others. From a textural standpoint, the formation of eutectics should give rise to special textures, and in some instances it has been observed to do so, but as a rule crystallization in silicates at high temperatures does not proceed with sufficient regularity to produce clearly defined textures, and in most instances differences between the crystals first to form (phenocrysts) and the portions last to crystallize out (groundmass, eutectic), are not well marked and the attention of the observer is directed chiefly to the crystal development of the individual crystals themselves. This condition, together with the fact that the preparations are usually examined in the powder form, tends greatly to reduce the value and usefulness of textural evidence in the microscopic investigation of such preparations.

The optic properties which are made use of in the microscopic examination of artifical products are the usual ones employed in mineral determinations in rock sections, and would require no comment at this point were it not for the fact that artificial preparations are usually much finer-grained than rock sections, and that in addition it is necessary to know the degree of accuracy of all measurements on such products. This has led the writer to make practical tests of available microscopic methods to establish their accuracy and adaptability to the new conditions found in artificial melts. In the course of the general investigation, several new methods were devised with special reference to the new requirements and have proved satisfactory. At the present time, the following methods and optic properties have been found most serviceable in the study of artificial preparations.

(1) *Refractive indices.*—In powder preparations the refractive indices are most readily determined by the immersion method (Schroeder van der Kolk)* in refractive liquids of known refractive index. On favorable clear grains the refractive indices can be determined by this method on grains measuring even less than ·01^{mm} in diameter and with a prob-

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* J. L. C. Schroeder van der Kolk, Zeitschr. f. wiss. Mikrosk., viii, 458, 1898; also F. E. Wright, T. M. P. M., xx, 239, 1900; this Journal (4), xxii, 385, 1904; xxvii, 35, 1909.

able error of about ±·002. The Becke line method can also often be used to advantage with refractive liquids. The refractive index of the liquids or mixtures of liquids used is determined on the total refractometer.

(2) *Birefringence.*—In this measurement the thickness of the plate is measured with the fine adjustment screw of the microscope by focusing a high power objective first on the upper surface of the plate or grain and then on the lower surface as it appears through the plate or grain itself. The apparent thickness thus obtained is then reduced to the true thickness by multiplying by the refractive index of the substance measured. The interference color is determined either with the Babinet compensator, the calibrated quartz wedge or the Michel-Lèvy interference-color chart. This is only an approximate method, and the results may be in error 10 per cent or more, but usually the percentage error is less and the numerical error is confined to the third decimal place.

(3) *Optic axial angles* are measured most readily in the powder section by means of the double screw micrometer ocular.* On favorable sections (·025^{mm} and over in diameter), the probable error of such measurements is about ± 1° in case both optic axes appear in the field of vision, and ± 3° in case only one optic axis is seen. For such measurements the grains should be immersed in a liquid of the refractive index β to eliminate errors caused by refraction on the uneven surfaces of the grains. In weakly birefracting substances and interrupted sections the axial bars are less sharply defined and the axial angle values obtained thereon are correspondingly less accurate.

(4) *Extinction angle.*—By use of the bi-quartz wedge plate† the position of total extinction can be determined on a single trial within ± 10′ on favorable sections. The extinction angle itself is the angle between a given crystallographic direction and a particular optical direction on a particular crystal face, and the accuracy with which it can be determined depends in part on the quality of the crystallographic development of the crystallite itself. Under favorable conditions of crystallographic development, extinction angles can be determined within 10′ and less, dependent on the number of readings taken, on crystals measuring only ·02–·03^{mm} in length.

(5) Color, pleochroism and absorption can usually be determined on grains measuring ·02^{mm} and over, and in certain instances on still smaller particles.

(6) Other properties, such as *dispersion* of the optic axes and bisectrices, and the general correlation of optic and crystallographic properties, can occasionally be accomplished on

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* This Journal (4), xxiv, 317–369, 1907.

† Ibid. (4), xxvi, 349–390, 1908.

isolated grains ·02–·03^{mm} in diameter, although for ease of manipulation and general accuracy larger grains and sections are preferable. It may be stated as a general rule that most of the optic properties can be determined with sufficient accuracy on grains measuring ·02–·05^{mm} in diameter, and certain optical properties on still smaller particles.

The great advantage of examining a preparation in powder form rather than in the thin section is two-fold: (1) by the use of refractive liquids, the refractive indices can be determined at once and traces of inhomogeneity in a compound appear most clearly if it be immersed in a liquid of the same refractive index; (2) the individual grains in the powder are isolated and can be rolled about in the liquid and examined along different directions if necessary. These two conditions are difficult to obtain in the thin section. The chief disadvantage of the examination of preparations in the powder form is the loss of texture. In the thin section, the texture or relation of the different crystallites to each other is much more clearly marked than in the haphazard particles of a powder preparation.

As a general rule, the morphologic development of crystallites from artificial melts is poor and crystals suitable for goniometric measurement are very rarely obtained. The crystal system of any compound has to be inferred, therefore, from the optic and crystallographic properties obtained by the microscopic investigation alone.

Briefly summarized, the optical investigation is adapted primarily to ascertain the mineral composition of the preparations of any given series, while the thermal work serves chiefly to establish the stability ranges of these compounds, both alone and in the aggregate, at different temperatures throughout the series. Other evidence—specific gravity determinations, crystallographic features, chemical behavior, etc.—tends further to supplement and to substantiate the thermal and optical data.

Evidence of this nature is in part chemical and part physical, and properly falls in the domain of physical chemistry, for its interpretation—wherefore the extreme importance of this science in the study of rock and ore formation.

Geologic data.—In the study of rocks their microscopic examination and bulk chemical analysis have heretofore received the most attention, and in fact petrography, which has primarily to do with rock description and classification, is a result of this study. The general science of rocks, however, demands not only rock description and classification, but also inquires into their formation and genesis, and this fact postulates thermal evidence. In the petrologic treatment of rocks, exact thermal evidence is just as essential as precise optical and chemical data, and this can only be supplied by experiment, since the amount of exact field evidence along these lines which has been obtained up to the present time is exceedingly slight.

A rock has been defined as a geologically independent part of the earth's lithosphere. It owes its position to the action of certain geologic forces and stands in causal relation to these. These forces are in part physical and crystallographic and in part chemical, and the rock as it appears to the geologist is the resultant end-product of a certain chemical system acted upon by the geologic forces; such forces, however, have not always remained the same throughout the history of any given rock, but have changed from time to time, either slowly or abruptly, and each change has brought with it new conditions of equilibrium in the crystallized mass, and possible consequent readjustment of mineral composition and texture. Such readjustment in texture and composition, however, is rarely complete, and the imprints or scars of each period of geologic activity are often clearly marked in the rock and to the trained eye serve to indicate its past history. The geologist has to rely chiefly on field evidence in his interpretation of the history of the earth, but such evidence is in large measure qualitative and does not of itself yield exact data along certain lines, particularly with reference to rock genesis and the actual character of subsequent transformations. This evidence is best obtained by direct experiment, by studying the crystallization of definite chemical systems under definite and determinable conditions of pressure and temperature. The difficulties of complicated texture and composition will undoubtedly be much diminished when the simpler chemical systems have been experimented upon and their behavior under different conditions studied. The technical difficulties in such problems are formidable, but once overcome in the simpler systems, they are mastered for all.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., June, 1909.

ART. XXXIII.—*Specific Heats of Silicates and Platinum*;*

by WALTER P. WHITE.

THE thermal properties of the silicates present several points of special interest. First is the value of the data in geological calculations; second, the light likely to be thrown on the nature of matter in general by researches through the long range of temperatures within which silicates are stable; and third, the opportunity offered of comparing the properties of the same substance in different physical states, for silica and many of its compounds, on account of their great sluggishness of transformation, can be carried over the same wide temperature range in the amorphous (vitreous) condition and in one or more different crystalline modifications. The present paper describes the beginnings of an investigation in this field upon the subject of specific heats. The present results are preliminary, covering but a small portion of the field and presenting values possibly differing by a few tenths of a per cent from those likely to be finally reached. Yet as practically no data whatever are now available through much of the region covered, and as the general properties of silicates are shown by a few members of the group, this preliminary publication has seemed worth making at the present time.

The method adopted as the standard is that in which the heated body is dropped from a furnace into a calorimeter. This, the oldest and most familiar method, seems also the most accurate, since the more delicate measurements are carried out at ordinary temperatures. Indeed, the single temperature determination necessary in the furnace is a source of greater error than all the rest of the process put together. The difficulty of operating a calorimeter near a furnace and of transferring the often white hot body into the water without thermal loss has often been counted very great, and its seriousness has been the subject of dispute among workers in this field. In the present work, it was found relatively easy to make all errors from this source certainly less, and probably very much less, than those arising from the lack of uniformity in the furnace temperature.

The experimental process naturally divides itself into three parts, the heating of the silicate, the transference to the calorimeter, and the measurement of the quantity of heat.

1. *Furnace temperature.*—The one great difficulty of high temperature measurements, that of obtaining uniformity of

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*Preliminary notices of this work have appeared in the Phys. Rev., xxvi, 536, 1908, and xxviii, 461, 1909.

temperature throughout the working chamber of the furnace, has thus far remained the chief difficulty in the present work. The working chamber of an electric resistance furnace is cylindrical. The heat is produced in the sides and escapes more or less through the ends, which are thus at a considerably lower temperature. Any body within will necessarily have an uneven temperature whose exact distribution depends on the body, as well as upon the furnace. The correction of this uneven temperature is somewhat troublesome, but will of course be essential as high temperature measurements become more exact.* Indeed, the comparative indifference to the question of furnace temperature distribution shown by the authors of much work already done is rather surprising. In the present case the furnace first used, whose working chamber was 16^{cm} high by 6^{cm} wide, showed by actual measurement differences of about 20° between different parts of the charge. The corresponding error, that is, the difference between the average temperature of the charge and that of the thermoelement which enters and measures it, would be under 10°, or one per cent, at 1000°. It very soon appeared that the precision attained in the other measurements was such as to justify an attempt to diminish this furnace irregularity and a new furnace was constructed 20^{cm} by $4{\cdot}5^{cm}$ in internal dimensions, in which partitions above and below the charge partially shut off the cooling effect of the ends. These partitions were of fire-clay 5^{mm} thick covered with platinum on the side toward the charge to give a reflecting surface. Thermoelectric measurements *outside* the crucible containing the charge now showed a maximum difference of 15° at 500° and of 6° at 1500° with a maximum systematic error at 500° of perhaps 0·5 per cent between the average temperature of the charge and that of the thermoelement used to measure it. The other sources of systematic error are small, and the greatest accidental errors in the final results (with two or three exceptions, which cannot be definitely accounted for) ranged from 0·5 per cent at the extreme to 0·2 per cent at the intermediate temperatures. These accidental errors are less for platinum and for a charge of glass which was melted into a single cake than for the other substances, which consisted of separate lumps. From this it would appear that the accidental errors are mainly connected with failure to hold the furnace temperature steady for a sufficient time, and are not to be taken as indicating a large systematic error. The present systematic error then may fairly be inferred from the temperature dis-

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*See, e. g., Some New Measurements with the Gas Thermometer, by Arthur L. Day and J. K. Clement, this Journal, xxvi, 412, 1908. Several other schemes for obtaining a very uniform high temperature are now under way.

tribution in the furnace and from the magnitude of the accidental errors, and on that basis is almost certainly under 1 per cent at the extreme and 0·5 per cent at the intermediate temperatures, and these values may be even smaller later on.

2. *The Drop.*—Two features characterize the process of dropping into the calorimeter and have rendered its results very satisfactory. (1) The enclosing crucible is first tared as to its thermal effect by dropping it alone, and the heat quantity thus obtained is then subtracted from subsequent determinations at the same temperature. This assumes that practically all the heat loss in dropping comes from the crucible alone, but as the time of fall is less than one-fourth of a second, and the greatest total loss of heat is only 4·7 per cent of that carried by the crucible, or 0·6 per cent of the total quantity measured, this assumption seems justified. In order to reduce, as far as possible, all variations in the heat loss, the crucible, when dropped by itself, is loaded with platinum so as to have about the same weight as at other times, and hence to pass through the surface of the water at the same speed. The specific heat of the platinum is so low that the error in the correction for it is certain to be under 0·1 per cent.*

(2) In the second place, the operations of dropping are performed as quickly as possible. This is accomplished as follows: (See fig. 1.) The bottom of the furnace is first dropped by pulling a latch (L), and falls into a box (B), which is hinged so as to swing horizontally out of the line of fall. A rapid glance at the furnace bottom tells whether it has fallen properly, that is, without the crucible, and with everything else that should come. The box is then swung aside, and as it moves it automatically shuts off the heating current of the furnace, and passes 40 amperes or so through a fine platinum wire by which the crucible is suspended,† allowing it to drop. The immediate return of the swinging box cuts off direct radiation from the furnace to the calorimeter. The whole operation requires about a second and the error from doubling the time, which has been several times measured, is negligible. Schemes for moving calorimeter or furnace have often been tried by others and were contemplated here when the present work was planned. But the device just described, which amounts to moving only a light wooden shield between the two, was tried first for its simplicity, and soon proved to be altogether the most reliable and effective, reducing the time to a minimum, yet giving the observer a chance to prevent many accidents

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* The error avoided by its use is probably no greater than this, but it seemed best to substitute a measureable error for a more uncertain one.

† This method was adopted from J. A. Harker, Specific Heat of Iron at High Temperatures, Phil. Mag., x, 430, 1905.

which result from almost any entirely automatic device. The water raised by the splash falls back into the calorimeter from the walls of an extension tube which is immediately afterward removed. The heat lost in this way, and from the few drops which occasionally escape altogether, is certainly negligible, for in one set of measurements, when 40^{cc} or so of splash water failed altogether of return to the calorimeter, the heat

Fig. 1.

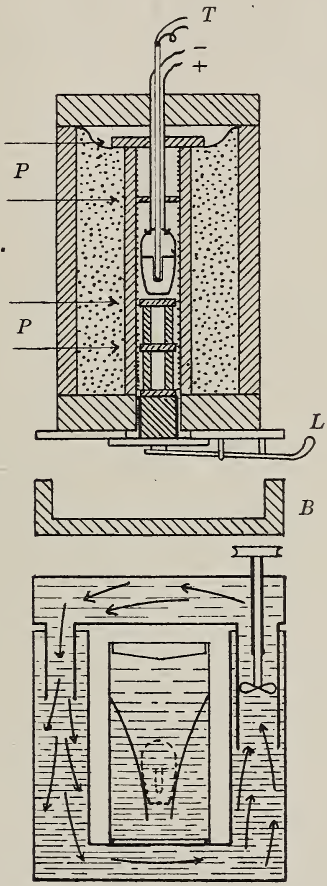

Fig. 1. Sectional view (somewhat simplified) of the furnace, swinging shield (*B*) and calorimeter, about 1/7th natural size. A porcelain tube carrying the thermoelement (*T*) enters the crucible from above. Pulling the latch (*L*) drops the furnace bottom and lower partitions (*P*) into the box (*B*), which at once swings aside and automatically shunts a heavy current through the wires (marked +, –) supporting the crucible and drops the latter in the (open) calorimeter below. The crucible comes to rest in the position indicated by the dotted outline.

thus lost was under 0·2 per cent of that in the usual silicate charge. The total resultant effect of this method of dropping is to reduce all its errors to accidental ones, whose magnitude can be gathered from the agreement of results. In a number of test drops with a heat quantity one-fourth that subsequently used, the variations were about 0·3 per cent. Assuming all these to have resulted from the dropping (which is highly improbable), this leaves for the resultant error from this cause less than 0·1 per cent.

*The Calorimeter.**—The distinguishing features of the calorimeter were mainly determined by its use in connection with the electric furnace. These are: (1) That the customary water jacket around the calorimeter includes a water cover and incloses it completely. This arrangement, however, is much more than a mere protection against the furnace. It has been independently adopted by several workers for determinations at ordinary temperatures,† and seems likely to become a customary feature in calorimetry of the greatest precision. The particular form of jacket cover is new, and appears to have some advantages in simplicity and convenience. It is shown in fig. 1. A single body of water is used, the portion in the cover being held up by the atmospheric pressure upon the free surface of the water in the jacket. It is made to circulate back and forth between the two by the action of a single propeller. The stirring and circulation are not in the least disturbed when the cover is swung aside to expose the calorimeter. (2) A second distinguishing feature is the use of a very accurate and sensitive multiple thermoelement as a calorimetric themometer. This choice was originally dictated by the fact that the furnace temperature measurement requires a thermoelement, therefore a potentiometer, and so it was more convenient to adapt the other temperature measurements to that instrument. The combination of thermoelement and potentiometer, however, has also proved advantageous in other ways. In addition to the general advantages of electrical over mercury thermometers and an accuracy about as great as that of the best resistance thermometers yet devised, it has the important advantage of readily permitting practically simultaneous measurements of a number of different temperatures. Its use enabled the determinations to be easily made by a single observer. (3) A third feature of the calorimeter is the attempt to avoid entirely bodies of uncertain temperature, chief of which ordinarily is the cover, separated by some

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* Preliminary notes on this calorimeter and the methods used with it have been given in Phys. Rev., xxv, 137, 1907; xxviii, 462, 1909.

† E. Bose and A. Müller., Gött. Nachr. 1906, 278; Beibl., xxxi, 432, 1907. Theodore W. Richards, S. J. Henderson and H. L. Frevert, Proc. Amer. Acad., xlii, 575, 1907; Zeitschr. phys. Chem., lix, 533, 1907.

distance from the water. The cover used here is in the form of a floating cup, and therefore had always the same temperature as the rest of the calorimeter surface. (4) An innovation has been made in calorimeter practice by working with temperature intervals much greater than usually employed (in one case, 23°, which is more than ten times the ordinary rise). This method increases the accuracy by diminishing the relative value of thermometric and other important errors. It requires an allowance for the variation in the cooling rate over the wide temperature intervals (deviation from Newton's law), but the difficulties of this correction have proved absolutely insignificant—far less than had been anticipated.*

No work has yet been done with this calorimeter of sufficient precision in other respects to fully test its accuracy. From the agreement (0·1 of 1 per cent) obtained in determinations of a heat quantity no more than one-sixth to one-twentieth of that usually employed, the accuracy is seen to be more than sufficient for all requirements of the present work.

The Specific Heats.—Specific heat, like density and conductivity, is a property varying with the temperature. Unlike them, it is almost never determined directly for any particular temperature. For the specific heat is, essentially, the heat given out by a body in falling through a given temperature interval divided by the interval. To give the true specific heat at any temperature, this interval should be infinitesimal; in practice, it is necessarily finite and often very large. The result obtained is the mean specific heat for the interval, from which the different true values occurring within the interval may vary widely. If a single interval only is employed, the relation between the mean and the true heat can not be determined; hence, unfortunately, most published values are of the mean heat only and give merely approximations to the true heats. If data are available for several different intervals all values of the true specific heat within them can generally be obtained. Three computations were required in the present work: (1) The mean heats were corrected down to zero, (2) to even temperatures at the upper end, and (3) the true specific heats were then derived from these corrected mean heats. The first correction was performed as follows: Let M_0 be the observed mean heat, found between the temperatures, θ_1 and θ_2. Let m_1 be the mean heat from 0 to θ_1, M_2 from 0 to θ_2, and M_3 from 0 to the even upper temperature Θ_3. Equating total heats, $M_2\theta_2 = M_0(\theta_2 - \theta_1) + m_1\theta_1$

$$\text{whence } M_2 = M_0 + (m_1 - M_0)\frac{\theta_1}{\theta_2} \qquad (1)$$

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*See Phys. Rev., xxviii, 462, 1909.

Before this equation can be applied, m_1 must be determined, which can be done with entirely sufficient accuracy as follows: If $f(\theta)$ is the total heat required to raise the body from 0 to θ,

$\frac{f(\theta)}{\theta}$ is the mean heat from 0 to θ, and $\frac{f(\theta_2)-f(\theta_1)}{\theta_2-\theta_1}$ (2) is the observed mean heat, M_0. If now $\theta_2 = 0$, this reduces to $\frac{f(\theta_1)}{\theta_1}$, that is, to m_1. If, therefore, the observed mean heats are plotted and the curve extrapolated to 0, the value of m_1 is obtained.*

For reducing the upper limit to a round number, an equation like (1) is not so easily applied, since the quantity corresponding to m_1 is here unknown, but if the interval of reduction is small, as it always was in the present work, it is possible to write

$$M_3 = M_2 + \triangle M \text{ and } \triangle M = \frac{dM}{d\theta} (\Theta_3\text{-}\theta_2)$$

by means of which the correction is easily made, taking $\frac{dM}{d\theta}$ from the tangent to the plotted curve.

The relation of the true to the mean heat may be expressed in two ways: (1) If the true heat is given by the polynomial $A + B\theta + C\theta^2 + \ldots$ the total heat from 0 to any temperature is the integral of this, or $A\theta + 2B\theta^2 + 3C\theta^3 + \ldots$ and the mean heat is $A + 2B\theta + 3C\theta^2 + \ldots$† If, then, the mean heat is expressed as a polynomial, the method of getting the true heat is obvious. (2) Unfortunately, the specific heat curves thus far obtained are not well represented even by polynomials with four constants, hence the following mothod, which may be applied graphically, was actually used. If the total heat is $f(\theta)$ and the mean heat $\frac{f(\theta)}{(\theta)}$, $f'(\theta)$ is the true specific heat. But if the mean heat is differentiated and then multiplied by θ, giving $f(\theta) - \frac{f(\theta)}{\theta}$ and to this is added the value of the

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* The approximations here made are easily seen, but as just stated, were not practically important in the present work. A more rigorous correction can be obtained by expressing the mean heat as a polynomial, that is, as equal to

$$A + B(\theta_2 - \theta_1) + C(\theta_2^2 + \theta_1\theta_2 + \theta_1^2) + \ldots \quad (3)$$

and thus determining A, B, C,

$$A + B\theta_2 + C\theta_2^2 + \ldots \quad (4)$$

is then the corrected mean heat. Both these expressions of course involve the error incidental to representing almost any actual physical function mathematically, but their difference will give very accurately the small correction required to reduce the lower limit to 0. Or (4) can be used to give m_1 and (1) then applied.

† Behn has already given a similar treatment, Drud. Ann., i, 263, 1900.

mean heat, the result is $f'(\theta)$ or the true heat. Hence if the mean heats are plotted and a curve drawn through them (fig. 2) and the tangent to any point n of the curve is produced to the y axis, say at q, the projection, pq, of the tangent on this axis, added to the mean heat, gives the true heat for the temperature of n.

Fig. 2.

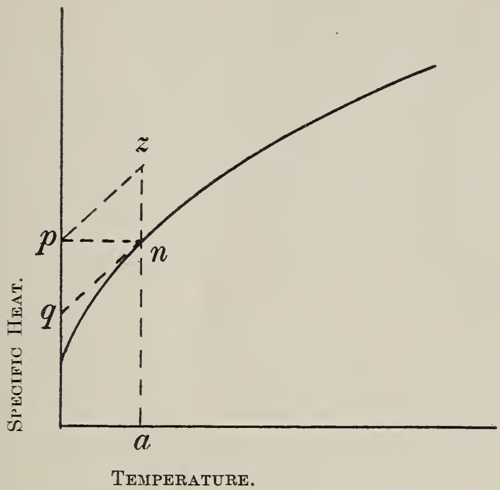

Fig. 2. Diagram illustrating graphic determination of true specific heat.

Experimental results.—Most of the results so far obtained are given in Tables 1 and 2, and graphically in figures 3 and 4. The values for orthoclase and the glass of the corresponding composition* were obtained with the wide furnace first used. Determinations of wollastonite and pseudo-wollastonite with this furnace ran about one per cent above those obtained later, hence the orthoclase and "orthoclase glass" results have been arbitrarily lowered two-thirds of a per cent. The platinum determinations were also made in this earlier furnace, but have not been altered, as the good thermal conductivity of the platinum probably reduced the systematic error considerably. Of course, these results are not quite as certain as the later ones. Otherwise, the results from 700° to 1300° probably contain no error exceeding 0·5 per cent. This is, of course, merely given as the result of careful consideration of all sources of error. Obviously, positive statements as to system-

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* Made by melting the orthoclase, which does not crystallize on cooling. See Day and Allen, Publication No. 31, Carnegie Institution of Washington, p. 50, 1904; this Journal, (4), xix, 120, 1905.

Table I.

Mean Specific Heats from Zero, of Platinum, Pseudo-wollastonite, Wollastonite, Orthoclase, Diopside, Quartz, Orthoclase Glass, and a Soft Tubing Glass.

Upper Temperature	Pt.	P–Woll.	Woll.	Or.	Di.	Qu.	Or. Glass	Soft Glass
100° --------	-----	----	·1833	----	·1919	·1840	----	·1977
	-----	----	·1833	----	·1905	·1851	----	·1974
	-----	----	----	----	·1920	----	----	----
500 --------	·03348	·2159	[·2180]	·2248	·2310	·2372	·2291	·24000
	·03355	·2169	·2169	·2246	·2308	·2368	·2304	·24077
	-----	----	‘2168	----	----	----	----	·2413 †
	-----	----	----	----	----	----	----	·2410 †
700 --------	·03423	----	·2286	----	·2420	[·2547]*	----	·2646
	·03428	----	·2289	----	·2422	·2559 *	----	·2639
	-----	----	----	----	----	·2556 *	----	----
800 --------	-----	----	----	·2401	----	----	·2465	----
	-----	----	----	·2402	----	----	·2473	----
900 --------	·03515	----	·2354	----	·2499	·2597 *	----	·2791
	·03514	----	·2355	----	·2488	·2594 *	----	·2796
	-----	----	----	----	·2483	----	----	----
1100 --------	·03573	·2380	[·2423]	----	----	----	----	----
	·03578	·2380	·2404	·2505	·2562	·2643 *	·2588	·2907
	-----	·2375	·2404	·2513	·2564	·2646 *	·2591	·2909
	-----	----	·2403	----	----	----	----	----
1300 --------	·03640	·2422	----	----	[.2613]	----	----	·2945
	·03647	·2416	----	----	·2596	----	----	·2949
	-----	----	----	----	·2601	----	----	·2972
	-----	----	----	----	----	----	----	[·2996]
1500 --------	·03675	----	----	----	----	----	----	·2999
	·03682	----	----	----	----	----	----	·2998
	-----	----	----	----	----	----	----	·3024

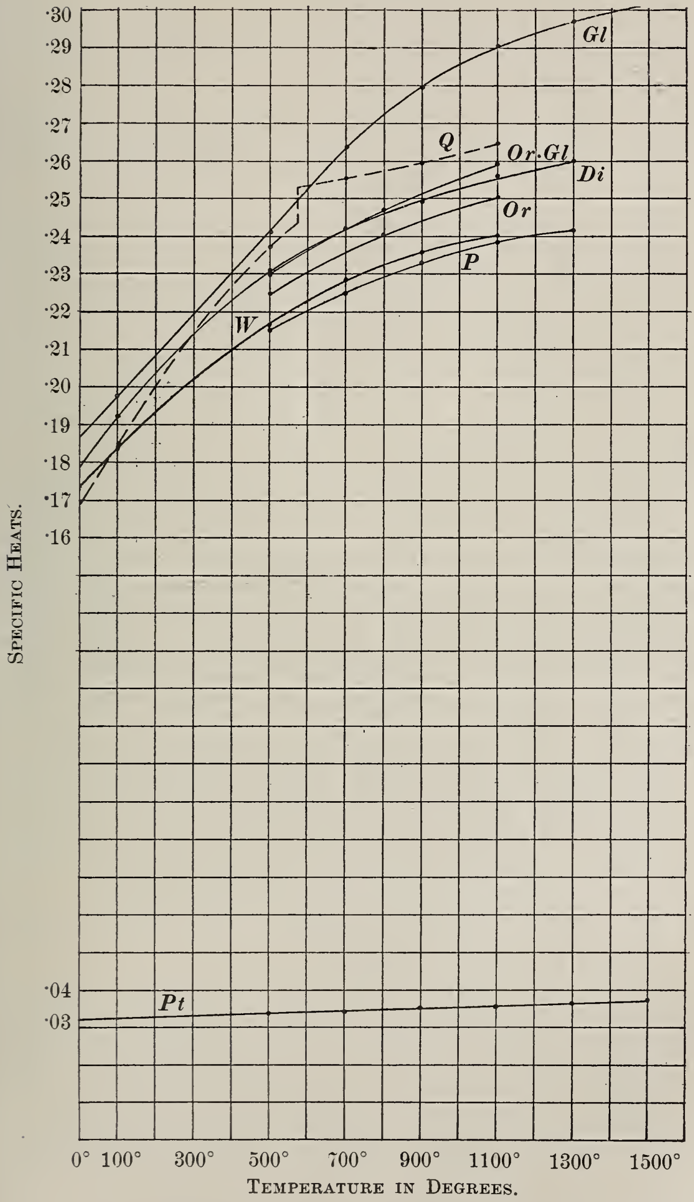
* Affected by the inversion at 575°. † Heated by lead bath.

Table II.

True Specific Heats of the Substances given in the preceding Table, except Quartz.

Temperature	Pt.	Woll.	P.Woll.	Or.	Di.	Or. Glass	Soft Glass
500 --------	·0356	·251	·250	·257	·262	·264	.298
700 --------	·0368	·263	----	----	·272		·324
800 --------	----	----	----	·272	----	·282	----
900 --------	·0380	·262		----	·281	----	·340
1100 --------	·0390	·261	·259	·279	·286	·297	·335
1300 --------	·0400	----	·257	----	·278	----	·333
1500 --------	·0407	----	----	----	----	----	·332

FIG. 3.



MEAN SPECIFIC HEATS OF TABLE I.

The maximum error is about equal to the difference of W and P at 1100°. Gl=Soft Glass, Or=Orthoclase, Or. Gl=Orthoclase Glass, Di=Diopside, W=Wollastonite, P=Pseudo-Wollastonite, Q=Quartz, Pt=Platinum.

atic error can seldom be based on one series of determinations. The results for quartz and platinum are several per cent lower than values given in Landolt and Börnstein. Two values for platinum at 600°, given by Plato, fall within half a per cent of the curve here given.* I have found no published data for the other substances as high as 500°.

Eighteen earlier determinations on wollastonite and pseudo-wollastonite have been omitted as now worthless and to avoid confusion. All the other observations are given, the rejected ones being bracketed.

In order to establish as certainly as possible the small difference between wollastonite and pseudo-wollastonite, special precautions were taken against any change in conditions between the two sets of determinations. The wollastonite was inverted to pseudo-wollastonite directly in the calorimetric crucible, so that the same lumps, in the same positions, served for both. As a check on possible systematic errors the pseudo-wollastonite determinations were repeated with half charges, showing very fair agreement.

The two values for soft glass at 500° first obtained seemed suspiciously low, as they cause a distinct reversal of the curvature. Two further determinations were therefore made in a new furnace, where the crucible was surrounded above and at the sides by a stirred bath of lead, and below by an electrically heated plate, whose temperature was observed and regulated. The results agreed to 0·1 per cent, and were only about 0·5 per cent above the old ones. This indicates that the peculiarity in the curve of this glass is really due to the substance itself, and also tends to confirm the estimate above (p. 335) as to the systematic error of the older observations at this temperature.

The accuracy of the true specific heats is less than that of the mean heats, from which they are derived. This is because the true heats are dependent on the differences of the others. The inversion in quartz at 575° renders more numerous data desirable before computing the true heat for it.

The mean specific heats of platinum and of diopside are expressed by the following formulas:

Pt ---------- $\cdot 03198 + 3\cdot 4 \times 10^{-6}\theta$
$CaMgSi_2O_6$ -- $\cdot 1779 + 1\cdot 516 \times 10^{-4}\theta - 1\cdot 047 \times 10^{-7}\theta^2 + 2\cdot 81 \times 10^{-11}\theta^3$

The agreement with the simple curve of platinum is as good as the original data, but the formula is not recommended for extrapolation. With diopside it amounts to only half a per cent, and a curve with one less coefficient is nearly as good.

For the results at 100° the heating was done in a steam bath.

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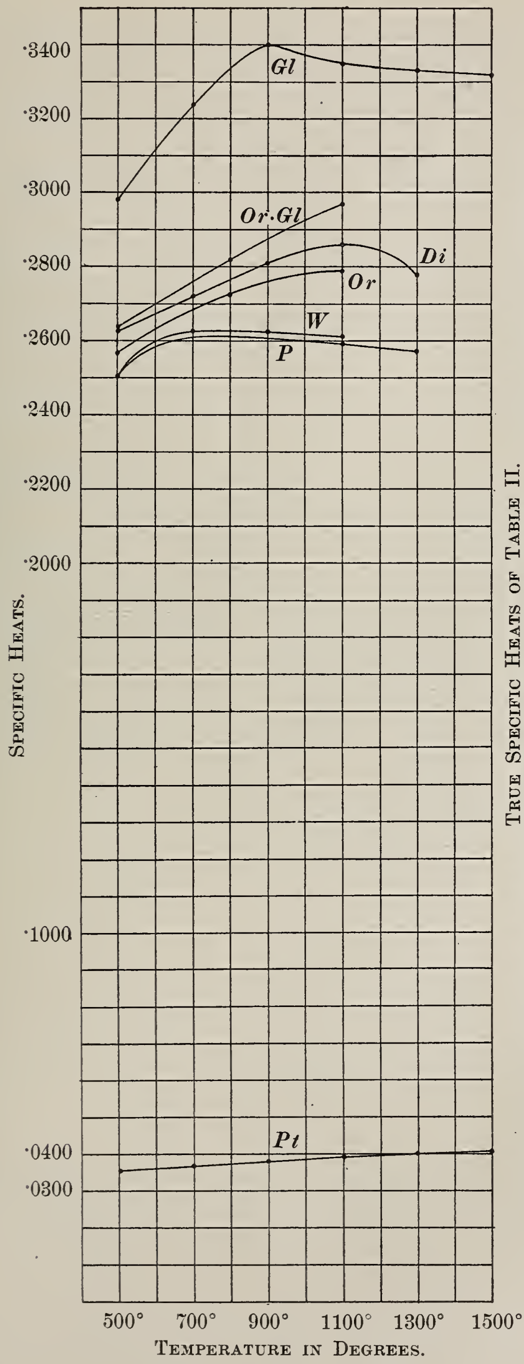
* W. Plato, Erstarrungserscheinungen an anorganischen Salzen und Salzgemischen. I, Zeitschr, phys. Chem., lv, 736, 1906.

Fig. 4.



True Specific Heats of Table II.

Errors here may equal the difference between the Or and Di curves. Gl=Soft Glass; Or=Orthoclase; Or. Gl=Orthoclase Glass; Di=Diopside; W=Wollastonite; P=Pseudo-Wollastonite; Pt=Platinum.

Summary.

1. For determining the specific heats of silicates up to 1500° C. the method of mixtures, in which the heated substance and containing crucible are dropped from a furnace into a calorimeter at room temperature, was selected as the most accurate.

2. The chief source of error is in the lack of uniformity in the furnace temperature. This has been diminished in some cases by the use of special forms of furnace.

3. The error introduced in the process of transferring from the furnace to the calorimeter is negligible. An electrical method of releasing the crucible greatly reduces the time required, and preliminary determinations made with the containing crucible alone eliminate what heat loss there is.

4. All temperatures, including that of the calorimeter, were read by thermoelements. By this means rapidity and simplicity of manipulation were secured.

5. The calorimeter was completely inclosed by its water jacket. An unusually large temperature rise (sometimes 23°) was successfully employed to increase accuracy.

6. Some simple ways of treating specific heats mathematically are given.

7. A consideration of the various sources of error indicates for the mean specific heats a final accuracy of better than 0·5 per cent at most temperatures. The true specific heats, derived from these, are less accurate.

Silicate specific heats show a considerable increase with temperature up to 700°, followed by a tendency to diminish at higher temperatures.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., July 15, 1909.

Art. XXXIV.—*The Complexity of Tellurium*; by Philip E. Browning and William R. Flint.

[Contributions from the Kent Chemical Laboratory, Yale Univ.—cciii.]

Although the consensus of opinion among chemists at present seems to favor the homogeneity of tellurium* and an atomic weight of 127·5, the recent work of Marckwald,† and the last report of the International Committee on Atomic Weights‡ seem to suggest that possibly the question of the atomic weight at least has not been definitely settled.

The work described in this paper was suggested by the observation that when water is added in large amount to a solution of tellurium tetrachloride, this compound is hydrolyzed and the greater part of the tellurous acid is precipitated, while some of the tellurium remains in solution however large the amount of water present.

This observation was apparently first made by Berzelius§ and later the method applied in a limited degree by Brauner‖ and by Baker and Bennett¶ to a process of fractionation.

It was further observed by us that the tellurium remaining in solution after the treatment with water and filtering may be completely precipitated as the dioxide by heating to boiling, treating first with ammonia and then with acetic acid in faint excess, as described in a previous paper from this laboratory.**

This procedure was applied with the result to be described, in order to determine whether by means of it any light might be obtained upon the possible complexity of tellurium.

About one hundred grams of crude tellurium, which had been extracted by hydrochloric acid from electrolytic copper residues, were subjected to a series of purification processes such as have been commonly used for the purpose of preparing pure material. This crude preparation was first twice fractionally precipitated by sulphur dioxide; then fused in portions, in hydrogen, with potassium cyanide, extracted with water and precipitated from solution by a current of air. It was next reprecipitated, by sulphur dioxide, from hydrochloric acid solution; was fused in hydrogen, and finally distilled, in a current of hydrogen, from porcelain boats in a porcelain tube.

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* Köthner, Ann., cccxix, 1; Gutbier, Sitzungsber. phys-med. Soc. Erlangen, xxxvii, 270; Lenher, J. Am. Chem. Soc., xxx, 387.

† Ber., xl, 4730. ‡ J. Am. Chem. Soc., xxxi, 1.

§ Ann. Chim. Phys. (2), lviii, 113. ‖ J. Chem. Soc., lv, 382.

¶ Ibid., xci, 1849. ** This Journal, xxviii, 112.

Ninety-two grams of this pure product were converted to tetrachloride and the solution, in as small amount of hydrochloric acid as possible, was diluted with four liters of boiling distilled water, and cooled. The precipitate, seventy-six grams of pure white, crystalline TeO_2, was removed and the filtrate was heated again to boiling, after which ammonia and then acetic acid in the smallest possible excess were added. When cold, thirty-eight grams of TeO_2 were obtained, more finely crystalline than the preceding fraction, but also pure white. The filtrate from this fraction contained no tellurium detectable by stannous chloride, and was consequently discarded.

These two fractions were next separately refractionated by an exact repetition of the process above described, each fraction secured being likewise refractionated, the three fractionations thus providing eight fractions, of which the last, about 1·5 gram, was set aside. Fraction two was combined with three, four with five, and six with seven, and each portion of the material refractionated, as was also fraction one. From this point on, the fractionation was carried out after the usual plan of fractional crystallizations, intermediate fractions being combined before retreatment, and those at the latter end of the series being removed when small in amount (from one to two grams). In this manner ten fractionations were performed, as a result of which were secured about fifty-nine grams of dioxide from the first, or water, end, and fifteen grams from the last, or ammonia-acetic acid, end of the series. Each of these portions was refractionated once, the water fraction (50 grams) of the first being denominated alpha, and the ammonia-acetic acid fraction (13 grams) of the latter, beta. The alpha and beta fractions were lastly converted to basic nitrate, the former by one and the latter by two crystallizations, according to the method described by Norris, Fay, and Edgerly.* It is to be noted that in the process of fractionation the material of each fraction had been crystallized out of a large amount of distilled water.

The alpha and beta fractions were subjected to analysis by three different methods: (1) the basic nitrate method; (2) the Gooch and Danner modification of Brauner's permanganate process;† and (3) the ammonia-acetic acid method previously described.

(1) After bringing the basic nitrate to constant weight at 140° as recommended by Norris,‡ carefully weighed portions were heated in platinum with a gradually increasing temperature for a period of five to six hours. The crucibles were contained in porcelain radiators, a porcelain dish being supported

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* Am. Chem. J., xxiii, 105.

† This Journal, xliv, 301.

‡ J. Am. Chem. Soc., xxviii, 1675.

above each in an inverted position to distribute the heat more evenly. Finally they were removed and ignited for a short time at dull redness until the dioxide had fused to a glassy condition. The weighings were conducted with properly standardized weights, by the method of vibrations, and the usual corrections were applied. The results are recorded in Table I.

TABLE I.

Alpha	$2TeO_2 . HNO_3$ taken gram.	TeO_2 found gram.	Per cent TeO_2 found
(1)	0·09575	0·07986	83·40
(2)	0·27354	0·22813	83·39
(3)	0·60237	0·50272	83·45
(4)	0·66288	0·55331	83·45
(5)	1·60542	1·33912	83·41
(6)	1·78565	1·48982	83·43
Beta			
(1)	0·08473	0·07081	83·57
(2)	0·23125	0·19256	83·63
(3)	0·87484	0·73306	83·79
(4)	0·39778	0·33232	83·56
(5)	0·39479	0·33005	83·60

The mean percentage of dioxide in alpha (83·42 per cent) gives an atomic weight of 126·53; that for beta (83·63 per cent), 128·97. It is thus apparent that the fractions are not homogeneous with each other, since they had been crystallized under precisely similar conditions, with due precautions to secure constancy of composition in each case, and with exactly similar treatment in the performance of the analyses.

(2) Analyses made by the permanganate process mentioned above confirmed this difference. The material was dissolved with two cubic centimeters of ten per cent potassium hydroxide and the solution was acidified with sulphuric acid (1:1), one cubic centimeter in excess, diluted to one hundred cubic centimeters with water, and treated with an excess of permanganate, oxalic acid being then added in excess. The mixture was then warmed nearly to boiling and the excess of oxalic acid determined by permanganate. The titrations were conducted in porcelain dishes. The results follow in Table II.

Computation from the permanganate required for the oxidation, in each case, gave a mean of 126·64 for alpha, and 128·77 for beta.

(3) A similar difference was again obtained by the ammonia-acetic acid process already referred to. The basic nitrate was dissolved with two cubic centimeters of hydrochloric acid, the

Table II.

	$2TeO_2 . HNO_3$ grm.	TeO_2 theory grm.	TeO_2 found grm.	Error on TeO_2 grm.	TeO_2 theory grm.	TeO_2 found grm.	Error on TeO_2 grm.
Alpha		(Te=126·5)			(Te=127·5)		
(1)	0·2537	0·2116	0·2119	+0·0003	0·2118	0·2132	+0·0014
(2)	0·2508	0·2092	0·2093	+0·0001	0·2094	0·2106	+0·0012
(3)	0·2521	0·2103	0·2102	—0·0001	0·2105	0·2115	+0·0010
(4)	0·2508	0·2092	0·2092	0·0000	0·2094	0·2105	+0·0011
(5)	0·2523	0·2104	0·2100	—0·0004	0·2107	0·2113	+0·0006
(6)	0·2511	0·2094	0·2092	—0·0002	0·2097	0·2105	+0·0008
Beta		(Te=128·9)			(Te=127·5)		
(1)	0·2504	0·2094	0·2095	+0·0001	0·2091	0·2077	—0·0014
(2)	0·2500	0·2090	0·2086	—0·0004	0·2087	0·2068	—0·0019
(3)	0·2505	0·2095	0·2095	0·0000	0·2092	0·2075	—0·0017
(4)	0·2505	0·2095	0·2095	0·0000	0·2092	0·2075	—0·0017
(5)	0·2504	0·2094	0·2100	+0·0006	0·2091	0·2083	—0·0008
(6)	0·2501	0·2091	0·2093	+0·0002	0·2088	0·2076	—0·0012

excess of acid removed as much as possible by careful evaporation; the dilution was with two hundred cubic centimeters of boiling distilled water, and the ammonia and acetic acid were added from burettes. Filtration was performed after standing over night. These results appear in Table III.

Table III.

	$2TeO_2 . HNO_3$ grm.	TeO_2 theory grm.	TeO_2 found grm.	Error grm.	Per cent TeO_2
Alpha		(Te=126·5)			
(1)	0·2506	0·2090	0.2093	+0·0003	83·51
(2)	0·2505	0·2089	0·2088	—0·0001	83·35
(3)	0·2529	0·2109	0·2108	—0·0001	83·35
(4)	0·2510	0·2094	0·2093	—0·0001	83·39
(5)	0·2507	0·2091	0·2091	0·0000	83·41
Beta		(Te=128·9)			
(1)	0·2512	0·2101	0·2097	—0·0004	83·48
(2)	0·2514	0·2102	0·2103	+0·0001	83·65
(3)	0·2504	0·2094	0·2095	+0·0001	83·66
(4)	0·2507	0·2096	0·2095	—0·0001	83·57
(5)	0·2612	0·2101	0·2100	—0·0001	83·60

For alpha the mean percentage of dioxide is 83·40 per cent, or Te=126·31; beta, 83·59 per cent, or Te=128·81.

SUMMARY OF ANALYSES.

Process	Alpha	Beta
Basic nitrate	126·53	128·97
Permanganate	126·64	128·77
Ammonia—acetic acid	126·31	128·81
Mean	126·49	128·85

It is seen that an atomic weight of 126·5 gives more satisfactory results for alpha, while neither 126·5 nor 127·5 will answer for beta.

Besides the experiments with the basic nitrate, just described, the following experiments upon the dioxide are to be noted. Two portions of tellurium dioxide from each fraction, prepared by the ignition of the basic nitrates, were dissolved in equal amounts of hydrochloric acid and treated with equal amounts of boiling distilled water. The results given in Table IV indicate different degrees of hydrolytic susceptibility on the part of the tetrachloride prepared from these fractions.

TABLE IV.

	TeO_2 taken grm.	TeO_2 found grm.	Percentage precipitated
(1)	0·3000	0·2521	84· %
(2)	0·3000	0·2602	86·7%
(3)	0·3000	0·2772	92·4%
(4)	0·3000	0·2806	93·5%

(1) and (2) were obtained from one fraction and (3) and (4) from the other. (1) and (3) stood 22 hours before filtration, (2) 26 hours, and (4) 18 hours.

A sample of tellurium dioxide obtained from the tellurium tetrachloride by several hot water precipitations, according to the procedure for the preparation of the alpha fraction, was analyzed by the permanganate process already described. The results of the analysis of this specially prepared dioxide, as given in Table V, show a close agreement with the analyses of the basic nitrate prepared from the alpha fraction and recorded in Table II.

TABLE V.

	TeO_2 taken grm.	TeO_2 found grm.	Error grm.	TeO_2 found grm.	Error grm.
		Te=126·5		Te=127·5	
(1)	0·3066	0·3064	−0·0002	0·3076	+0·0010
(2)	0·2723	0·2719	−0·0004	0·2729	+0·0006
(3)	0·2229	0·2228	−0·0001	0·2243	+0·0014
(4)	0·2220	0·2220	0·0000	0·2235	+0·0015

It consequently appears from the analyses by three different methods that, in the end fractions obtained by fractional hydrolysis of tellurium tetrachloride prepared from the carefully purified element, tellurium, seems to possess different atomic weights. It is not claimed that these atomic weights have been determined with the utmost accuracy. The two fractions, however, have been in each case treated exactly alike, in a manner entirely competent to show at least approximately whatever difference there might be. The preparations have been carefully examined to discover the presence of any impurities which might cause the difference, but no such impurities have been found. At present, therefore, there seems to be no explanation of the differences found other than the complexity of the original substance. The investigations just described are of necessity preliminary in character, and the results of a more extended study of this fractionation process, already begun by the latter of the two collaborators, will be published as soon as practicable.

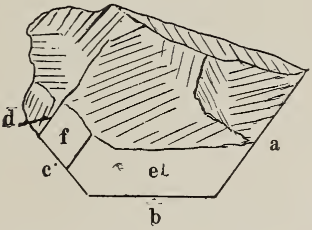
Art. XXXV.—*Arizonite, Ferric Metatitanate*;* by Chase Palmer.

The mineral, which is the subject of this paper, was found on a mining claim belonging to Mr. A. G. Alm, about 25 miles southeast of the railroad station at Hackberry, Arizona. It was received at the U. S. Geological Survey by Mr. Frank L. Hess, along with some gadolinite, of which the new mineral was suspected to be a variety. The prevailing rock in the locality of the find is granite. The new mineral occurs together with typical gadolinite in a pegmatite dike. The gadolinite gelatinizes with hydrochloric acid; has a specific gravity 4·28; and a partial analysis shows that it contains:

Silica (SiO_2)	24·41	per cent.
Yttria earths	36·86	" "
Ceria earths	11·50	" "
Beryllia (BeO)	11·50	" "
Ferrous oxide (FeO)	11·56	" "
	95·83	" "

The new mineral occurs for the most part in irregular masses outwardly resembling the gadolinite with which it is associated. The weathered surfaces of the two minerals, however, differ, those of the new mineral being somewhat lighter, in color inclining to grey. The vitreous appearance of fracture surfaces of the gadolinite, moreover, is wanting in the new mineral.

Fig. 1.



One specimen showed crystalline form. This was referred to Dr. F. E. Wright, who has very kindly furnished the following preliminary crystallographic description of the mineral:

"For the crystallographic examination and determination of this mineral only one large and imperfectly formed crystal was available (fig. 1, actual size, side view). Its faces were rounded and unequally developed, and the crystal angles could

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* Published by permission of the Director of the U. S. Geological Survey.

be measured only approximately with a hand goniometer and with a probable error of several degrees. So far as could be determined from the forms present, the crystal system is probably monoclinic, in which case the plane of projection of fig. 1 is the plane of symmetry and the indices of the different faces are $a(001)$, $b(100)$, $c(\bar{1}01)$, $d(00\bar{1})$, $e(110)$ and $f(\bar{1}12)$. Between these faces the following angles were measured:

Reflection.

$001 : 100$	$= 125°$	fair	$100 : 00\bar{1}$	$= 51°$	poor
$001 : 110$	$= 106°$	"	$100 : \bar{1}12$	$= 90°$	"
$001 : \bar{1}01$	$= 80°$	poor	$110 : \bar{1}01$	$= 117°$	"
$001 : \bar{1}12$	$= 60°$	"	$110 : \bar{1}12$	$= 130°$	"
$100 : 110$	$= 123°$	"	$\bar{1}01 : 00\bar{1}$	$= 110°$	"
$100 : \bar{1}01$	$= 130°$	"	$\bar{1}12 : \bar{1}01$	$= 124°$	"

These values are not sufficiently accurate for a satisfactory determination of the axial ratios, but it is approximately $a : b : c = 1{\cdot}88 : 1 : 2{\cdot}37$; $\beta = 125°$.

In the above calculation of the axial ratios, it is assumed that the plane of projection in fig. 1 is a plane of symmetry. No proof of this, however, was obtained, and it is possible that the crystal system is triclinic or other system instead of monoclinic. Etch figures would be of service in deciding definitely the system from the single crystal available.

"Under the microscope the larger particles of even fine powder are opaque, but the very thin edges of minute slivers are deep red in transmitted light, highly refracting ($n > 1{\cdot}84$) and of medium birefringence. Pleochroism is barely noticeable in shades of deep red with absorption $\mathfrak{r} > \mathfrak{a}$. In the thin section noticeable amounts, about 4 per cent or less even in the freshest material, of a colorless to pale brownish yellow, highly refracting substance, uniaxial and optically negative, occurs and agrees in its optic properties with anatase.

"A thin section made from an alteration product of the new mineral shows that, as the alteration of the latter proceeds, the amount of the anatase present increases until finally practically the entire substance is changed to a meshwork of fine anatase aggregates. The luster becomes dull and lithoid, and the color changes gradually from dark steel grey to a brownish yellow. In the freshest material there is also present in minute grains and laths a colorless, strongly refracting and birefracting mineral which is not anatase but is negligible in amount, and, so far as its effect on the chemical analysis of this material is concerned may be disregarded."

The mineral is decomposed completely by hot concentrated sulphuric acid. The residue, insoluble in the sulphuric acid, contained all of the silica and about one half of one per cent pure titanic oxide. The latter is apparently present in the mineral in the free state. This view accords with Dr. Wright's observation that the mineral contains a small quantity of anatase.

The following analytical results were obtained by decomposing the mineral with sulphuric acid:

Analysis.

			Per cent	Ratio
Insoluble	TiO_2	0·56	“ “	
	SiO_2	1·02	“ “	
Soluble	FeO	·70	“ “	
	Fe_2O_3	38·38	“ “	1·
	TiO_2	58·26	“ “	3·03
	$H_2O-110°$	·18	“ “	
	$H_3O+110°$	1·02	“ “	
		100·12	“ “	

The close ratio of ferric oxide to titanic oxide, viz., 1 : 3·03, indicates that the mineral is really ferric metatitanate, $Fe_2O_3.3TiO_2$ or $Fe_2Ti_3O_9$. Moreover, the crystallographic de terminations strengthen the view that this titanate of iron cannot be assigned to any known species, but is entirely new. I propose to name it *Arizonite.*

Arizonite is apparently without cleavage. The fracture is subconchoidal. It is brittle, with hardness between 5 and 6, specific gravity 4·25. Fresh fracture surfaces are dark steel grey in color and metallic to submetallic in luster. Its streak is brown. The mineral is opaque and is not magnetic. It is partially decomposed by hydrochloric acid. The filtered solution, containing ferric chloride, responds readily to the oxidation and reduction tests for titanium.

There appears to be no authentic prior record of the occurrence in nature of a simple ferric metatitanate ($Fe_2O_3.3TiO_2$). The literature furnishes, however, a few examples of the existence of this form of titanic iron, either admixed or combined with ferrous titanate ($FeO.TiO_2$), the usual form of natural titanic iron.

Rammelsberg[*] recognized that a variety of iserine, described by him as of uncertain crystallographic form, is a titanate of ferrous and ferric oxides. Upon readjustment of the analytical data as cited by Rammelsberg, it appears that his mineral consists essentially of 60 per cent ferrous titanate ($FeO.TiO_2$), ilmenite, and 40 per cent ferric titanate ($Fe_2O_3.3TiO_2$), arizonite. Attention is also called to the low specific gravity of this iserine, viz., 4·4. This is much under the specific gravity of the

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[*] Pogg. Ann., civ, 532, 1858.

more common varieties of ilmenite (4·7 to 4·9), and is only slightly above that of arizonite (4·25).

Even more closely related to arizonite is a titanic iron sand from Brazil, described by J. B. Mackintosh.* The numerical data there given for the Brazilian sand are:

TiO_2	59·20
Fe_2O_3	32·11
FeO	4·90
MnO	1·73
SiO_2	1·16
	99·10

Specific gravity 4·2.

Mackintosh's results indicate that the mineral was a mixture of about 85 per cent ferric titanate, with 15 per cent ferrous titanate. The concordance of the specific gravity of the Brazilian sand with that of arizonite, and the preponderance in it of ferric titanate, suggest the propriety of regarding this sand† as an impure arizonite rather than as a variety of ilmenite.

Chemical Laboratory,
U. S. Geological Survey.

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* This Journal, xxix, p. 342, 1885.

† Dana, System of Mineralogy, 6th edition, page 218. Ilmenite, Brazil, Analysis No. 5.

Art. XXXVI.—*On the Retardation of Alpha Rays by Metals and Gases;* by T. S. Taylor.

[Contributions from the Sloane Physical Laboratory of Yale University.]

Introduction.

In a preliminary paper* "On the Retardation of Alpha Rays by Metal Foils and its Variation with the Speed of the Alpha Particles," the writer described some experiments which showed clearly that the air-equivalents of metal foils decrease with the range of the alpha particles entering the foils.† By "air equivalent" is meant the amount by which the range of the a-particles in air is cut down by their passage through the foil. It was shown that the change in the air-equivalents is small for thin foils of the lighter metals when the speed of the alpha particles entering the sheets is high; but, when the speed of the particles is low for thin sheets or when the sheets are thicker, the change becomes quite marked. A comparison of the change for sheets of different metals of nearly equal air-equivalent showed the rate of change to be in the order of the atomic weights of the metals. The results obtained in these experiments were not sufficient to furnish an explanation of the phenomenon; but the continuation of the experiments during the last year under somewhat different conditions has furnished results which do lead to conclusions of some interest.

Scattering of the Alpha Rays.

In the determination of the variation in the air-equivalents with the speed of the alpha particle as described in the paper cited above, the source of rays (polonium), with the metal sheet over it, was set at such a distance from the ionization chamber that some part of the top, or nearly horizontal portion, of the Bragg ionization curve fell within the ionization chamber. A slight increase in the range of the particle in this portion of the curve corresponds to a considerable increase in the ionization.

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* This Journal, vol. xxvi, pp. 169–179, Sept., 1908.

† The phenomenon upon which this work was based was first observed by Mme. Curie and has later been investigated by several others. Bragg & Kleeman (Phil. Mag., Sept, 1905, and April, 1907) observed that the stopping power of a metal was not independent of the speed. Kucera & Masek (Phys. Zeitschr., xix, pp. 630–40, 1906), and Meitner (Phys. Zeitschr., viii, 489, 1907), ascribe the effect to a difference in the amount of scattering. McClung (Phil. Mag., Jan., 1906), Rutherford (Phil. Mag., Aug., 1906), and Levin (Phys. Zeitschr., xv, 519–521, 1906) obtained results which indicate that each successive layer of aluminium foil diminishes the range of the a-particle by the same amount.

With the polonium set at a definite distance from the ionization chamber, it was found that, when the metal sheet was moved away from the polonium toward the ionization chamber, the ionization increased. This increase in the ionization was attributed to the alpha particle having a greater velocity (or range) upon entering the chamber when the sheet was near the chamber than it had when the sheet was at a distance from the chamber. Hence the metal sheet did not cut down the range of the particle so much when the sheet was at a distance from the polonium as it did when near the polonium. As a preliminary to more extensive experiments by this method, two tests were made to ascertain whether a scattering of the rays could explain the increase in the ionization observed when the metal sheets were moved away from the polonium towards the ionization chamber.

First test.—Any marked scattering of the rays by the foils would change the shape of the cone of rays and especially the form of the top portion of the cone. The slope of the top, or nearly horizontal portion, of the Bragg ionization curve, as well as the value of the maximum ionization, depend upon the form of the cone of rays arriving at the ionization chamber. Thus, if scattering of the rays exist to a very marked degree, it might be expected that differences between the slope and form of the two Bragg curves obtained with and without the metal foil over the polonium could be readily detected. With polonium as the source of rays, numerous determinations of the Bragg curves, both with and without the various foils over the polonium, were made. A study of these curves showed them to run parallel to each other and to give the same value of the maximum ionization. The effect of putting the foils over the polonium was merely to diminish all the ordinates of the curves by the same amount.

Second test.—An iris diaphragm whose circular opening could be adjusted to any desired diameter between 0·5 and 5·5$^{\mathrm{cms}}$ was constructed of thin sheets of brass and placed directly below the ionization chamber. The center of the opening of the diaphragm was directly below the center of the ionization chamber. With the source of rays (radium C) at such a distance from the ionization chamber that the chamber cut the top portion of the Bragg curve, the ionization was measured for various distances of the metal sheets above the source of rays; first with the diaphragm open and then with the opening in the diaphragm of such diameter as to just limit the geometrical beam of rays, or to cut off the edge of the beam. For any given position of the sheet above the source of rays, the ionization was always greater when the diaphragm was completely open than it was when the diaphragm just limited the beam.

However, the difference between the ionization in the two cases was a constant value for all positions of the metal sheets above the source of rays. This difference would not be a constant quantity if the scattering of the rays was the occasion of the increase in the ionization produced by moving the metal sheets away from the source of rays. On the contrary, the difference between the ionizations with and without the diaphragm limiting the geometrical beam of rays would be greater when the sheet is far away from the source of rays than when it is near the source of rays if scattering of the rays by the foils was the cause of the increase in the ionization. The fact that the ionization was greater with the diaphragm open than when it just limited the cone of rays signifies that more alpha particles get into the ionization chamber in the former than in the latter case, and therefore confirms the existence of scattering of the rays by metal foils as found by Geiger.*

These two methods of investigation, although in the case of the latter showing the existence of the scattering of the rays, seem to be sufficient to preclude scattering as an explanation for the so-called decrease in the air-equivalents of the metal sheets as they are moved away from the polonium. By measuring the ionizations with and without the diaphragm limiting the cone of rays when there was not a metal sheet over the source of rays, it was found that the ionization was greater in the latter than in the former case, which shows that the rays are scattered by air as well as by metals. These methods, however, are not particularly suitable for measuring the amount of the scattering, and hence no comparison as to how much each metal scatters the rays was attempted. The important fact is that the effect under consideration is not influenced by the scattering of the rays.

Continuation of Experiments.

In the first experiments polonium had been used as the source of rays, but in order to extend the study to alpha particles of higher range, radium C has been used in the present experiments. This made it possible to use foils of greater thickness than had been previously used. A thin aluminium foil covered with a thin coating of lacquer was put directly over a capsule containing a thin film of pure radium bromide in order to prevent escape of the emanation. The hole in the brass plug over the radium bromide was of such dimensions that the cone of rays emerging from it fell well within the limits of the ionization chamber. The radium bromide was set at such a distance from the ionization chamber that a part

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*Proceedings of the Royal Society, Series A, vol. lxxxi, No. 546, page 174.

of the top, or slightly inclined portion, of the Bragg ionization curve due to the α-particles from radium C fell within the chamber, and the air-equivalents of the various metal sheets determined at various points in the path of the rays in exactly the same manner as that used in the first experiments.* The rays of shorter range than those of radium C had no effect upon the results since they did not reach the ionization chamber. Beta and gamma rays are also given off by the radium bromide, but the ionization produced by them can be considered as a constant value over the part of the path used and consequently the effect due to them is only a shifting of the curves to the right parallel to themselves, which would have no effect upon the results under consideration.

In Column 1, Table I, are given the different metal sheets used in the experiments. Column 2 contains the thickness in centimeters of the respective sheets. Column 3 has the air-equivalents of the sheets as measured directly when the sheets were nearest the source of rays. Column 4 contains the ratios of the air-equivalents to the thickness of the respective metals. The last three lines of the table will be referred to later. The air-equivalents of the sheets given in Column 1, Table I, as determined by an improved method for any position of this sheet, are given in Table II.

The aluminum foil over the radium to prevent the escape of the emanation cut down the range of the α-particles $0·46^{\mathrm{cm}}$.

TABLE I.

I Metal Sheets	II Thickness in cms.	III Air-equivalent in cms.	IV Ratio
A Au	$1·27 \times 10^{-4}$	0·719	$5·67 \times 10^{3}$
B Au	$1·74 \times 10^{-4}$	0·980	$5·63 \times 10^{3}$
C Au	$2·50 \times 10^{-4}$	1·375	$5·50 \times 10^{3}$
D Au	$3·50 \times 10^{-4}$	1·900	$5·42 \times 10^{3}$
A Sn	$3·86 \times 10^{-4}$	1·011	$2·61 \times 10^{3}$
B Sn	$7·99 \times 10^{-4}$	1·995	$2·48 \times 10^{3}$
A Pb	$2·84 \times 10^{-4}$	1·104	$3·88 \times 10^{3}$
B Pb	$4·11 \times 10^{-4}$	1·396	$3·40 \times 10^{3}$
C Pb	$6·95 \times 10^{-4}$	2·325	$3·34 \times 10^{3}$
A Al	$3·30 \times 10^{-4}$	0·597	$1·79 \times 10^{3}$
B Al	$6·77 \times 10^{-4}$	1·209	$1·79 \times 10^{3}$
C Al	$10·40 \times 10^{-4}$	1·803	$1·73 \times 10^{3}$
D Al	$16·10 \times 10^{-4}$	2·672	$1·66 \times 10^{3}$
Hydrogen Sheets			
A hydrogen	1·07	0·231	$2·15 \times 10^{-1}$
B hydrogen	1·93	0·428	$2·21 \times 10^{-1}$
C hydrogen	3·23	0·762	$2·36 \times 10^{-1}$

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* Loc. cit., pp. 173–175.

TABLE II.

Range in cms. of entering *a*-particle	A Al	B Al	C Al	D Al	A Au	B Au	C Au	D Au
5·7	0·597	1·209	1·803	2·672	0·719	0·980	1·375	1·900
5·3	0·597	1·206	1·792	2·659	0·706	0·966	1·352	1·869
4·9	0·597	1·202	1·781	2·644	0·693	0·947	1·328	1·837
4·5	0·597	1·198	1·769	2·628	0·680	0·929	1·303	1·802
4·1	0·597	1·193	1·757	2·608	0·668	0·910	1·276	1·763
3·7	0·597	1·187	1·742	2·582	0·657	0·889	1·248	1·720
3·3	0·596	1·178	1·724		0·644	0·866	1·214	1·659
2·9	0·595	1·168	1·705		0·630	0·837	1·178	1·598
2·5	0·592	1·152			0·616	0·805	1·127	
2·1	0·584	1·131			0·600	0·757		
1·7	0·570				0·582			
1·3	0·555							

Range in cms. of entering *a*-particle	A Sn	B Sn	A Pb	B Pb	C Pb	Paper	Celloidin
5·7	1·011	1·995	1·104	1·396	2·325	1·020	0·520
5·3	1·002	1·980	1·085	1·371	2·596	“	“
4·9	0·993	1·960	1·064	1·343	2·260	“	“
4·5	0·984	1·938	1·042	1·320	2·220	“	“
4·1	0·971	1·914	1·020	1·289	2·180	“	“
3·7	0·957	1·884	0·999	1·263	2·124	“	“
3·3	0·941	1·845	0·977	1·232	2·046	“	“
2·9	0·923	1·795	0·950	1·200		“	“
2·5	0·902		0·923	1·163		“	“
2·1	0·882		0·888				“
1·7	0·853						“
1·3							“

The height of the plug containing the radium was 0·9$^{\mathrm{cm}}$ above the radium. Therefore the maximum available range of the alpha particles entering the sheet is 5·70. The values of the air-equivalents for each of the metal sheets in Table II represent the average results obtained from a series of from six to ten separate determinations, the details of which have been omitted for the sake of brevity.

Experiments were also made with sheets of paper and celloidin.* Two sheets of paper of about 1 and 2$^{\mathrm{cms}}$ air-equivalent respectively, and three sheets of celloidin of air-equivalents of the order of 0·5, 1·0 and 2·0$^{\mathrm{cms}}$ respectively were used. For these sheets of paper and celloidin, the ionization did not increase as the sheets were moved away from the radium, but

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* Celloidin is a specially pure preparation of collodion.

had the same value for all positions of the sheets, and hence their air-equivalents remained constant.

The behavior of the sheets of paper and celloidin, the atomic weights* of which are about the same as that of air, suggested the idea of undertaking to obtain sheets of some substance such as hydrogen whose atomic weight is less than that of air. For this purpose a ring about one centimeter wide was cut from a brass tube six centimeters in diameter and two small brass tubes were put in the ring diametrically opposite each other. Thin films of celloidin were stretched across each side of the ring and held in place by universal wax. This formed a cell which could be filled with hydrogen and then used in the same manner as the metal foils. To be certain that the cell was always full of hydrogen a slight current of the gas was kept flowing through it all the time during an experiment. A current of air was kept circulating through the case surrounding the apparatus in order to prevent the hydrogen, that might possibly leak from the cell, from entering the ionization chamber. The air-equivalent of the hydrogen cell or sheet when $0{\cdot}9^{cm}$ from the radium was determined by plotting the ionization curve first with hydrogen and then with air in the cell. The ordinates of the latter curve were all increased by the thickness of the cell of hydrogen, which gave the position of the curve if the cell had been evacuated. The difference between the ordinates of the two curves corresponding to a given abscissa was the air-equivalent of the hydrogen sheet.

When the cell containing the hydrogen was moved away from the radium, which was kept at a given position as in the previous cases, it was found that the ionization *decreased*, which signified that the total range in air of the alpha particle was less when the hydrogen sheet was *far away* from the radium than when it was *near* the radium. Thus the amount by which the range of the alpha particle was cut down by its passage through the cell was greater when the cell was at a distance from the radium than it was when it was near the radium. Consequently the air-equivalent of the hydrogen cell *increased* as the range of the entering alpha particle *decreased*. The particles had to pass through the celloidin sheets, but this did not influence the effect because, as we have seen, the amount by which the range was cut down by the celloidin sheets was constant for all positions of the cell. Determinations of the air-equivalents in centimeters of three hydrogen cells given in Table I were made for various distances of the cell from the radium and the results obtained are recorded in Table III.

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* By atomic weight of air, paper and celloidin is meant the average weight of the constituent atoms.

TABLE III.

Range of the α-particle upon entering the hydrogen	A hydrogen	B hydrogen	C hydrogen
5·2	0·231	0·428	0·762
4·8	0·235	0·434	0·776
4·4	0·241	0·442	0·791
4·0	0·247	0·451	0·807
3·6	0·254	0·460	0·831
3·2	0·262	0·470	0·861
2·8	0·271	0·483	0·896
2·4	0·283	0·499	0·938

The reason the maximum range here is 5·2$^{\text{cms}}$ instead of 5·7$^{\text{cms}}$, as it was in Table II, is because the air-equivalent of the lower film of celloidin must be subtracted, since the alpha particles must pass through it before entering the hydrogen. The air-equivalent of the lower film was 0·5$^{\text{cms}}$.

Although the air-equivalents of the celloidin sheets remained constant, it seemed probable, from the behavior of the hydrogen sheets, that if the same experiments were performed in an atmosphere of hydrogen, the hydrogen-equivalent[*] of the celloidin sheet would not remain constant, but would decrease as the range of the alpha particles decreased. To investigate this point the apparatus was enclosed in an air-tight sheet iron case, which by several partial evacuations and refillings could be filled with practically pure hydrogen. With polonium as the source of rays the hydrogen-equivalents in centimeters of sheets of celloidin, aluminium, tin, and gold were determined for various distances of the sheets from the polonium. Only the results for the celloidin and A gold are given in Table IV, as they are sufficient to illustrate the point in question.

TABLE IV.

Range in H of entering particle	13·0	12·6	12·2	11·8	11·4	11·0	10·6	10·2	9·8	9·4
Celloidin	23·20	23·08	22·96	22·80	22·64	22·48	22·32	22·16	21·88	21·60
A Gold	27·97	27·55	27·11	26·67	26·23	25·75	25·17	24·49	23·91	23·01

The curves in figure 1 represent the results recorded in Tables II, III, and IV. By noting the slopes of the curves some comparison of the rates, at which the air-equivalents of the various sheets change, can be obtained. Taking the general slope of each curve and dividing it into the air-equivalent of the corresponding sheet when 0·9$^{\text{cms}}$ from the radium, it is found that for a given metal the quotient thus

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[*] The hydrogen-equivalent is the amount by which the range of the α-particles in *hydrogen* is cut down by their passage through the sheet.

obtained is nearly constant for all the sheets of the metal. This is shown in column 4, Table V. Thus for sheets of the same metal the rate at which the air-equivalent of each sheet changes with a change in the range of the entering α-particles, is proportional to its air-equivalent when nearest the radium. The approximately constant numbers in column 6, Table V show that the percentage rate of change in the air-equivalent for any metal is nearly proportional to the square root of the atomic weight. The agreement of the values in columns 4 and 6, Table V is as good as could be expected since the slopes of the curves in figure 1 could only be determined roughly. The proportionality is indeed only approximate, since the curve for any one sheet does not have a constant slope.

Table V.

Sheets	Slopes of curves	Air-equivalents	Ratio	$\sqrt{\text{atomic wt.}}$	Mean ratio $\sqrt{\text{atomic wt.}}$
A Au	0·032	0·719	$2·24 \times 10^1$		
B Au	0·051	0·980	$1·92 \times 10^1$		
C Au	0·064	1·375	$2·15 \times 10^1$		
D Au	0·100	1·900	$1·90 \times 10^1$	14·05	28·80
A Sn	0·032	1·011	$3·16 \times 10^1$		
B Sn	0·063	1·995	$3·17 \times 10^1$	10·91	34·34
A Pb	0·053	1·104	$2·08 \times 10^1$		
B Pb	0·071	1·396	$1·96 \times 10^1$		
C Pb	0·110	2·325	$2·11 \times 10^1$	14·38	29·38
A Al	0·010	0·597	$5·97 \times 10^1$		
B Al	0·020	1·209	$6·04 \times 10^1$		
C Al	0·033	1·803	$5·48 \times 10^1$	5·19	30·41
D Al	0·045	2·672	$5·93 \times 10^1$		
A H	−0·020	0·231	$1·16 \times 10^1$		
B H	−0·034	0·428	$1·17 \times 10^1$		
C H	−0·064	0·762	$1·19 \times 10^1$		

For the thin sheet of aluminium the air-equivalent is almost constant for the higher ranges or speeds, but as the speed of the entering alpha particle decreases the air-equivalent decreases slowly and in the lower ranges the decrease becomes quite apparent. For the thicker sheets of aluminium the change is more marked even for the higher ranges. The statements of McClung, Levin and Rutherford that equal successive layers of aluminium foil diminish the range of the alpha particles by equal amounts seem to hold true for thin sheets of foil when the range is high; but when the metal sheet is thicker, or for thin sheets when the range is low, it does not hold. The slight difference, however, in the air-equivalent of the thin foil when near and far away from the polonium, would scarcely

Fig. 1.

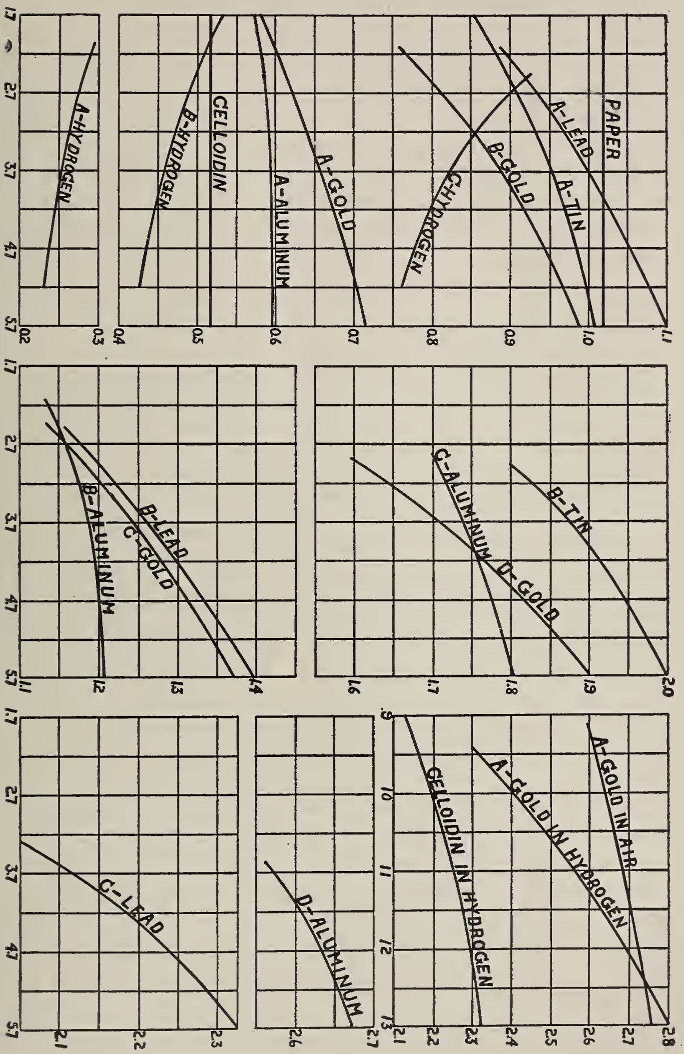

Fig. 1. For the portion of the figure containing the curves designated as: "A Gold in Hydrogen," "Celloidin in Hydrogen," and "A Gold in Air," the abscissas are the ranges in *hydrogen* of the alpha particles when they enter the sheets and the ordinates are the hydrogen-equivalents of the sheets. For the other part of the figure the abscissas are the ranges in *air* of the alpha particles when they enter the sheets and the ordinates are the air-equivalents.

be detected by measuring directly the air-equivalent in the two positions. This is probably the explanation of the above statements by McClung, Levin and Rutherford.

Since the air-equivalent of a metal sheet decreases with the speed of the alpha particle entering it, the ratio of the air-equivalent to the thickness of a given sheet of metal should be less than the same ratio for a thinner sheet of the same metal. This is shown to be true by the last column of Table I. For the hydrogen sheets, on the contrary, the same ratio should increase as the thickness of the cell or sheet of hydrogen increases. This is also confirmed by the last column of Table I.

While the air-equivalent of the sheet of celloidin remains constant the hydrogen-equivalent of the same does not remain constant but decreases as the range of the alpha particle in hydrogen decreases. The curve "Celloidin in Hydrogen," figure 1, which was plotted from the results recorded in Table IV, illustrates this point. It is to be noted also from the curve "A Gold in Hydrogen," figure 1, that the rate at which the *hydrogen-equivalent* of the A gold decreases is much greater than the rate at which its *air-equivalent* decreases. The curve designated "A Gold in Air," figure 1, is the portion of the "A Gold" curve in the same figure that lies to the left of the abscissa, 3·0. The coördinates of that portion of the curve are magnified about 4 2/3 times so as to be plotted on the same scale as the curves obtained in the hydrogen atmosphere. 4 2/3 is the ratio of the thickness of a hydrogen sheet to its air-equivalent when near the radium. The slope of the curve "A Gold in Air" is practically the same as that of "Celloidin in Hydrogen," as can be seen from the figure. The angle which the curve "A Gold in Hydrogen" makes with the curve "A Gold in Air" is about the same as the angle which the curve "Celloidin in Hydrogen" makes with the axis of abscissas. The slope of the curve "A Gold in Hydrogen" is nearly 3 3/4 times the slope of the curve "Celloidin in Hydrogen." But 3 3/4 is the ratio of the square root of the atomic weight of gold to that of air $\left[\sqrt{\frac{197}{14}} = 3{\cdot}75+\right]$ Hence the rates, at which the *hydrogen-equivalents* of the gold and celloidin sheets decrease with the speed of the alpha particle entering the sheets, are proportional to the square roots of their respective atomic weights. Moreover the slope of the curve "Celloidin in Hydrogen" is numerically equal (but of opposite sign) to the slope of the curve "B Hydrogen" in air. The hydrogen-equivalent of the celloidin sheet was somewhat larger than the thickness of the "B Hydrogen" cell, but it seems entirely proper to conclude that the rate at which the hydrogen-equivalent of the celloidin sheet *decreases* with the speed of the alpha particle, is the same as the rate at which the air-equivalent of the B hydrogen *increases* as the speed of the entering alpha particle decreases.

The possibility that the observed variations in the ionization, which have been taken to be the measures of the changes in the air-equivalents, may be due to secondary rays is precluded by the fact that numerous direct determinations of the Bragg ionization curves with and without the metal sheets near the polonium and again near the ionization chamber, showed no irregularities in the curves, as would be expected were secondary rays present in any appreciable amount. The behavior of the air-equivalents of the hydrogen sheets in no way conforms to what might be expected to be produced by secondary rays.

The increasing of the air-equivalents of the hydrogen sheets and the decreasing of the hydrogen-equivalents of the celloidin sheets when moved away from the source of rays gave occasion for suspecting that some differences might be found to exist between the Bragg ionization curves obtained in atmospheres of air and hydrogen respectively. To determine these curves use was made of an apparatus, constructed for Mr. F. E. Wheelock of this Laboratory, which was similar to the one used thus far in the work except that the vessel enclosing the main part of the apparatus could be completely exhausted. To make any comparison of the two ionization curves it was necessary to determine them under similar conditions, i. e. the same source of rays was used in the two cases and the pressure of the air was so reduced as to make the range of the a-particles in air equal to their range in hydrogen at normal pressure. Polonium was used as the source of rays and several Bragg curves were obtained in hydrogen at normal pressure and in air at a reduced pressure of about 17^{cms} of mercury. Two of the curves are shown in figure 2. The dotted portion of each curve is assumed to be the form it would take were it possible to move the polonium entirely up to the ionization chamber. At all events, these assumed portions of the curves can differ but little from what the actual curves would be.

It is to be observed that the two curves in figure 2 present slight differences in form. The probable interpretation of these differences will now be considered. Any given abscissa of either curve is a measure of the ionization produced by the particles in the gas in the chamber when the polonium was at a distance from the chamber represented by the ordinate corresponding to the given abscissa. Consequently the total area enclosed by the two axes of reference and either curve is proportional to the total ionization produced in the gas in which the curve was determined. By measuring these areas with a planimeter, it was found they were equal. This confirms the observations by Bragg* that the total ionization produced by the alpha particle in air is the same as that in hydrogen. From the curves of figure 2 it is seen that when the speed of the *a*-particle is high more ions are produced per centimeter of path in air than in hydrogen, but when the speed is low more ions are produced per centimeter in hydrogen than in air.

FIG. 2.

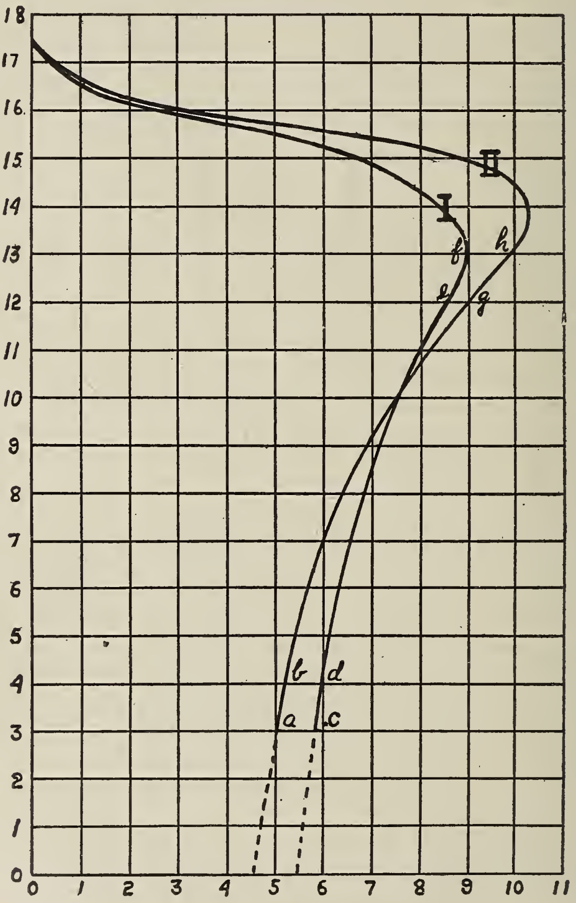

FIG. 2. The ordinates of the curves are the distances in centimeters of the polonium from the ionization chamber. The abscissas are the deflections in centimeters of the electrometer needle per second. Curve I was obtained in air at a reduced pressure of about 17 centimeters of mercury. Curve II was obtained in hydrogen at normal pressure.

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* Phil. Mag., March, 1907, p. 333.

Let us suppose that for a given speed of the alpha particle the amount of energy required to produce an ion is the same in all substances. Then for air we would have the relation

$$dI_a = -f(V)\,dE_a.$$

The corresponding relation in hydrogen is

$$dI_h = -f(V)\,dE_h.$$

Dividing the former by the latter we have

$$\frac{dI_a}{dI_h} = \frac{f(V)\,dE_a}{f(V)\,dE_h}$$

which for a given speed V in each gas reduces to

$$\frac{dI_a}{dI_h} = \frac{dE_a}{dE_h}.$$

From this it is seen that for a given speed of the alpha particle the ratio, of the rates of the consumption of the energy in producing ions in air and hydrogen, is equal to the ratio of the rates at which the ionization is produced in the respective gases. On the basis of our hypothesis let us consider the ratios of the energies consumed in the 4th and 13th centimeters (fig. 2) of the path of the particle in air and hydrogen. This ratio for the fourth centimeter of the path is proportional to $\frac{\text{area } cd\ 43\ c}{\text{area } ab\ 43\ a}$ since the areas are proportional to the ionizations produced in the gases. The corresponding ratio for the 13th centimeter is equal to $\frac{\text{area } c,\, f,\, 13,\, 12,\, e,}{\text{area } g,\, h,\, 13,\, 12,\, g}$. The former ratio is seen from the figure to be greater than the latter. Moreover, it is also seen that the ratio of the energy of the α-particle absorbed by any given centimeter of air to the energy absorbed by the corresponding centimeter of hydrogen, is always greater than the corresponding ratio for the centimeter just beyond the given one. This is in agreement with the results obtained for the air-equivalents of the hydrogen cells; because the increase in their air-equivalents as the range decreases is due to the fact that the ratio of the energy absorbed by the hydrogen cell to the energy that would be consumed by the air which it displaces, continually increases as the cell is moved away from the source of rays. The thicker the cell the more rapid would be the rate of increase, as could be seen by comparing the areas which represent the ionization in, say two centimeters of air and hydrogen respectively in figure 3 in two different positions. The increase in the ratio of the energies consumed in air and hydrogen respectively is in agreement also with the decrease in the hydrogen-equivalent of the celloidin film.

Still making use of our hypothesis, the ratio of the energy, consumed in the 9th and 10th centimeters of air at reduced pressure, to that consumed in the same centimeters of hydrogen at normal pressure, is expressed by the fraction $\frac{312}{305}$. The same ratio for the 13th and 14th centimeters is $\frac{77}{83}$. These ratios were obtained by measuring with a planimeter the areas in figure 2. The former ratio divided by the latter gives 1·10. Since the hydrogen equivalent of the celloidin film is but slightly more than two centimeters, the ratio of its values at 9 and 13^{cms} respectively from the polonium should be the same as the above ratio. The hydrogen equivalents of the film in the two positions (see figure 1) are 2·320 and $2{\cdot}120^{\text{cms}}$ respectively, and the ratio of the former to the latter is 1·09, which differs little from the calculated ratio 1·10 given above. Hence it is seen that the differences between the curves of figure 2 are sufficient to account for the change in the hydrogen-equivalent of the celloidin film and consequently for the increase in the air-equivalents of the hydrogen sheets when moved away from the source of rays. This agreement between the relative ionizations and the relative losses of energy of the particle in the two gases gives a considerable degree of probability to our hypothesis connecting the relation of the ionization produced to the energy consumed.

The experimental results show that the air-equivalents of the metal sheets decrease with the speed of the alpha particle, and hence the ratio of the energy of the alpha particle, consumed by its passage through a sheet of metal, to the energy that would be consumed by one centimeter of air at the same point in the path of the particle, decreases as the range of the alpha particle decreases. The behavior of the metal sheets relative to the air is entirely analogous to the behavior of the air, or celloidin relative to hydrogen. Consequently if it were possible to measure the ionization produced by the alpha particle at different points in the path of the rays in the metals, and if the ionization curves were plotted on the same scale as those shown for air and hydrogen, figure 2, it is probable that the curves for the metals would all present some such differences from the air curve as those existing between the air and hydrogen curves. Moreover these differences might be expected to be such as to agree with the different rates at which the air-equivalents of the different metal sheets change.

In the upper portion, the curve for gold would probably lie within the air curve about the same amount as the air curve does within the hydrogen curve, figure 2; and in the lower portion the curve for gold would probably lie without the air curve by the same amount as the air curve does without the hydrogen curve. At least some such differences would be in accordance with the square root law, since the square root of the atomic weight of air is a mean proportional between the square root of the atomic weights of gold and hydrogen. The curves for the other metals would occupy intermediate positions between the curves for gold and air.

We have seen that for different metal sheets of about the same air-equivalents the rates at which the air-equivalents decrease with speed of the alpha particle, are proportional to the square roots of the atomic weights of the respective metals. Consequently the rates of decrease of the ratios of the quantities of energy used up in the sheets to the energy that would be consumed by a centimeter of air at the same positions in the path of the particle decreases also as the square roots of the atomic weights of the respective metals. On the basis of our hypothesis that for a given speed of the alpha particle the same amount of energy is required to produce an ion in all substances, and from the results in our experiments, it appears indeed very probable that for the high velocities the alpha particle loses its energy, in going through a substance, more rapidly the higher the atomic weight of the substance; but as the speed of the alpha particle becomes less this changes, until for the low velocities the loss of the energy of the particle is more *rapid* the lower the atomic weight of the substance.

In conclusion I wish to express my gratitude to Professor Bumstead, at whose suggestion these experiments were undertaken, for his valuable suggestions and interest in the work; also to Professor Boltwood, who kindly prepared the polonium and secured the radium bromide for me, and gave me many valuable suggestions.

Summary of Results.

1. The air-equivalents of metal foils decrease with the speed of the alpha particles entering them. The decrease is very small for thin foils of the lighter metals when the speed of the a-particles is high; but when the speed is low for thin sheets, or when the sheets are thicker, the change becomes more marked. For different sheets of the same metal the rates of change are proportional to the air-equivalents of the sheets. For sheets of different metals of equal air-equivalents the rates of change are approximately proportional to the square roots of the respective atomic weights.

2. The air-equivalents of hydrogen cells or sheets *increase* as the speed of the entering particle decreases, while the air-equivalents of sheets of paper and celloidin remains constant.

3. The hydrogen-equivalents of sheets of paper, films of celloidin, and air do not remain constant but decrease as the speed of the alpha particle decreases. The rate at which the hydrogen-equivalent of a celloidin film decreases with the speed of the entering α-particle is numerically equal to the rate at which the air-equivalent of a hydrogen sheet of corresponding thickness increases.

4. The result obtained by Bragg, that the total ionization produced by the alpha particle in air is the same as that in hydrogen, is confirmed by a more direct method.

5. It is very probable that for the high ranges the α-particle loses its energy, in passing through substances, more rapidly the higher the atomic weight of the substance; but that this difference decreases slowly until in the low ranges the loss of energy is the more rapid the lower the atomic weight of the substance.

6. A comparison of the Bragg curves for air and hydrogen indicates that the large ionization at low ranges (knee of the curve) is due at least in part to the fact that the particle loses its energy more rapidly in this part of the range; and not wholly to the higher ionizing efficiency of particles of low speed.

Art. XXXVII.—*The Physiography of the Central Andes: II. The Eastern Andes;* by Isaiah Bowman.

During the field examination of the eastern Andes of Bolivia, not only were the local geology and physiography noted, but many widely separated commanding points were also gained from which was viewed the general aspect of the eastern plateau. The results were everywhere strikingly similar. The conclusions based upon an examination of these wide expanses of the plateau surface and their discordance with respect to structure harmonize with those resting upon a study of drainage features and lead inevitably to the conclusion that peneplanation is the dominating fact in the physiography of the region. Lest it seem that this view is held without sufficient consideration of the geologic structure and of the relation of the plane of baseleveling to it, the following geologic descriptions are introduced. They but serve to emphasize the conclusions already stated by the striking structural variations they indicate, variations practically unexpressed in the plateau surface, save where residual masses have survived the baseleveling process.

Geologic Features.

The rocks of the eastern Andes may be roughly classified into two great groups, the eastern sandstone series and the western schistose series. The sandstone series consists of shales, conglomerates and sandstones; the schistose series consists of slates, quartzites and quartzite schists. Both are structurally disturbed, but the disturbances in the schists are of a more profound order and have resulted in metamorphic effects whereby the schistose structure was imposed upon the entire western series. Every gradation may be observed in the scale of these disturbances from those of microscopic to those of mountainous proportions. In all sections there are notable intrusions of igneous material. In the slates of Santa Vera Cruz it is quartz porphyry and granite, the lead, tin and zinc of commercial interest being found in fissures of the quartz porphyry. In the western series of rocks almost every variety of geologic structure may be found in a day's ride from east to west across the grain of the rock; in the eastern sandstone series the structures vary from folds to block-faulted monoclines, so that within limited areas the latter structures show dip and strike of more or less constant value.

Specific structural values for definite localities are almost without physiographic interest or importance, so generally do they conform to the generalizations that have just been noted.

The dip and strike are, as a rule, so irregular in value that both specific and general values are almost without interest. In general it may be said that the prevailing dip of the sandstones along the lower Juntas valley north and northeast of Cochabamba is northwest or toward the axis of the eastern highland, though there are frequent and important exceptions to this generalization. Of frequent occurrence are zones of crushing where incredibly minute and numerous disturbances have resulted from the adjustment of great block-like masses of sandstone on either side. There is notably greater textural firmness to the sandstones and shales toward the west; those toward the east are often so pliable as to fall to pieces readily, though there are again many local exceptions to this condition. The whole sandstone series is unfossiliferous so far as we examined it and is marked throughout by the development of coarse conglomeratic deposits interstratified with finer textured layers. In many localities cross-bedding may be observed, and this feature, while not everywhere displayed, is about as common in one section as another. An unusual feature of the easternmost sandstone on the margin of the plains was the presence in the parting planes of small clay lenses a foot or so in length and a few inches thick. The clay is moderately dry and soft and falls out of a broken fragment of sandstone as a separate unit. These clay lenses, from their position and the frequency of their occurrence, appear to indicate a general process of flood-plain erosion whereby a clay layer resting upon sand was eroded to the point where only

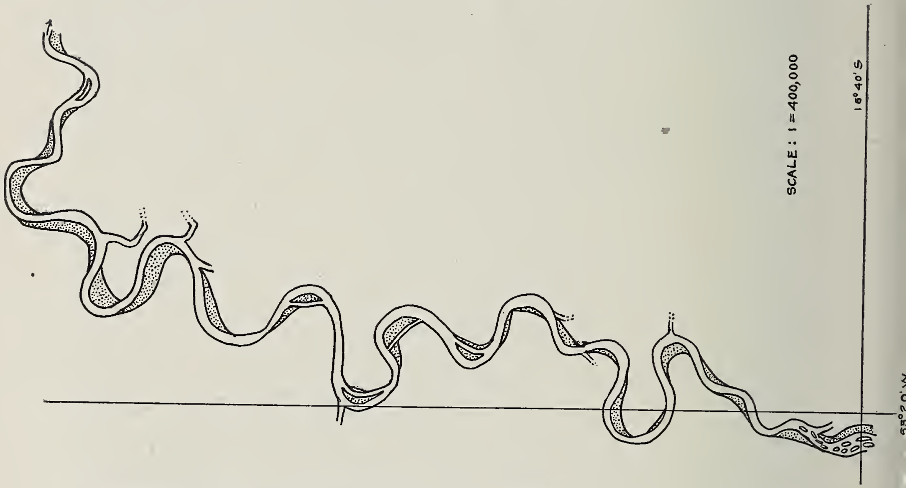

Fig. 13. Rio Chaparé, eastern Bolivia, for fifty miles below Santa Rosa.

fragments of the clay remained. These were then covered by a second thick layer of sand and thus preserved.

The frequent occurrence of irregular and locally variable conglomeratic layers throughout the sandstone series, the interstratified clay lenses, the great thickness of the conglomerates and coarse sandstones, establish the conclusion that the sandstone series represents a piedmont river deposit. As an index of the close proximity of highland and aggrading flood-plain upon which such coarse deposits were formed, might be cited our observations upon the degree of coarseness of the bar material in the Chaparé downstream from San Antonio at the base of the Andes, fig. 13. At and above San Antonio the river is full of bowlders, often of huge size. At Santa Rosa, less than twenty miles away, the bars are composed of sand and pebbles of 8, 10, and 12 inches in diameter. Six miles below Santa Rosa one can discern pebbles only in patches upon the upstream sides of the bars, and fifteen miles farther downstream, or forty miles by river and perhaps twenty or twenty-five miles in a direct line from the edge of the existing upland, it is impossible to find any pebbles whatever,—the bars are wholly of sand. Such a distribution of coarse material along the valley of the Chaparé supplies data for the conclusion that the eastern front of the Andes was not far from the conglomerate formation of a particular locality and that the progressive eastward uplift of the Andes accounts for the wide distribution of the conglomerates throughout the sandstone series that now constitutes the eastern border of the Andine Cordillera. This conclusion seems the more warrantable because the conditions of lofty mountains and adjacent flat plains, with a strong and sudden break between, are now most favorable for the widest development of conglomerates; and as we have just seen, these are now formed in an extremely narrow belt (less than thirty miles) along the mountain front.

This brief outline of the geologic structure of the region may now well be followed by a word concerning the geologic history of the central Andes as a whole. With these three groups of facts before us—the structure, the geologic history, and the general physiographic aspect of the region—we shall be prepared to discuss the physiographic conclusions and the detailed stratigraphic and physiographic evidence upon which they rest.

The western or Maritime Andes consist chiefly of Mesozoic strata interstratified with and intruded by igneous rocks, and are of later age than the eastern Andes. The whole rock series is surmounted, in addition, by volcanic piles which give whatever variety and mountain alignment these mountains possess.

Between the western and the eastern Andes are ridges and masses of rock of Devonian, Carboniferous, and Permian or Triassic age, rising out of a great infilling mass of alluvial material derived from the adjacent highlands. In northern Bolivia the first foldings of the eastern Andes took place in very early times, but the effects of erosion and of tectonic changes were such as to bring the entire area below sea level at the beginning of the Carboniferous period. Before the close of this period renewed elevation again exposed the sediments to erosion, and from this time on the geologic history of the region consists of erosion and renewed folding accompanied by the intrusion of those granitic masses which now constitute the cores of the highest chains. So far as the geologic record has been interpreted, the movements in the eastern Andes seem to have been resumed in the Cretaceous although the main central chain was outlined and its position established at the end of the Paleozoic.*

The widely extended development of the Cretaceous hints at the significant erosion that must have taken place on the land area formed by the mountain-making movement at the end of the Paleozoic. "Marine Kreidefossilien wurden in fast allen Teilen der Anden gefunden . . ." †

The western Andes, on the other hand, were a region of sedimentation down to the end of the Mesozoic, when mountain-making movements began. This movement, however, must be distinguished from that now in progress and described in the preceding chapter. The movements of to-day are broad and regional in their effects, and distinctly non-mountainous in character.

In southern and eastern Bolivia the sediments are Cambrian and Lower Silurian, with some traces of Devonian and Carboniferous. The farther back geologic researches extend the clearer it becomes established how general is the occurrence of Paleozoic strata. Silurian and Devonian rocks occur widely distributed in every region of the continent, even in the region which now has the most conspicuous mountain heights, Silurian fossils occurring in the slates that form the highest portions of the Nevadas of Quimsa Cruz, at 17,000 ft. Thick strata of red Cretaceous sandstones also occur which, under ordinary circumstances, are only preserved in troughs and folds. This entire system of sediments "lies concordantly" except

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*Condensed and adapted from the accounts of the geologic history of the region in Expedition to Caupolican Bolivia, 1901–1902, by J. W. Evans (The Geog. Jour., vol. xxii, pp. 631–634 et al., 1903); Süd- und Mittel-Amerika, by W. Sievers (1903); The Continent of South America, by A. J. Herbertson (1900) (Mills' International Geography, pp. 816–817); Archhelenis und Archinotis, by H. von Ihering (1907).

† Archhelenis und Archinotis, 1907, p. 95.

where the original concordance has been disturbed by differential movements associated with the folding which involved both sedimentary series. In general the folding took place on very broad lines and individual folds are often of great dimensions.* The whole of the great region near and south of Tarija consists of a series of shallow folds or parallel chains of Silurian, Devonian, and Cretaceous deposits. The red Cretaceous sandstones rim the outer edge of the entire eastern Andine section of Bolivia, extending as far as explorations have been carried toward the north. On the south they are said by Hoek to be of marine origin; but farther north, in the valley of the Juntas and the San Antonio they are certainly terrestrial, carrying large proportions of conglomerate and cross-bedded sandstone. (See p. 374.) Evans has described† the northeastern section of this marginal band of sandstones as consisting of soft red sandstones and conglomerates overlying harder sandstones in some places, or as a conglomerate resting upon soft shaly sandstones in others. These observations and our own in the valleys farther south, the Juntas and San Antonio, certainly deny a marine origin to the sandstone series of northeastern Bolivia. The age of the sandstones in these northern locations is not fixed, however. They appear to have the same structural relations to the older Paleozoic rocks as the known Cretaceous sandstones farther south and like them also to have been folded on a huge scale and in places block-faulted. It may be necessary to assign a later age to them, a point which seems difficult to clear up in the absence of fossils. The equivalency of the non-marine red sandstones of eastern Bolivia and the marine red beds of known Cretaceous age farther south was first suggested by Steinmann in 1891.‡

The latest deposits in the central Andes whose age has been positively identified by fossils are of Eocene age and occur along the coast of northern and central Chile. Probable Miocene beds of very limited development occur in northern Chile,§ but neither they nor the Eocene shared in the mountain-making movements of the late Mesozoic. The marine Triassic and Jurassic have a very limited development and occur only between 5° and 25° south latitude in the coastal section of the continent.‖

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* Exploration in Bolivia, by H. Hoek (The Geog. Jour., vol. xxv, p. 510, 1905).

† Expedition to Caupolican Bolivia, 1901–1902, by J. W. Evans (The Geograph. Jour., vol. xxii, pp. 607 and 614, 1903).

‡ A Sketch of the Geology of South America (Amer. Naturalist, vol. xxv, p. 858, 1891).

§ Möricke and Steinmann (N. Jahrbuch f. Min., etc., Beilagebd. x, p. 533, 1896).

‖ A Sketch of the Geology of South America. A paper by A. Steinmann read before the Geol. Soc. Am., Aug. 25, 1891 (Amer. Naturalist, vol. xxv. p. 857, Oct., 1891).

The wide distribution of Cretaceous strata in Bolivia, northern Peru, and Ecuador indicates how late was the formation of the western Andes. Von Ihering* assigns the uplift of the western ranges to the point of continuous extent from Colombia to Bolivia to the same period in which the Antarctic region sank and the bridge between Australia and South America was destroyed, that is, to the Eocene. However, the absence of the Upper Cretaceous and the exceedingly limited occurrence of the Eocene, and probable Miocene, upon the western fringe of the Maritime Andes would seem to be sufficient ground for concluding that the formation of the western ranges was well begun in the Cretaceous, though undoubtedly completed only in the early Tertiary.

The occurrence of a widely developed baseleveled surface now uplifted to a great height furnishes an interesting means for the determination of recent geologic history. The common physiographic history of the eastern and western Andes, as indicated by the equally well-developed peneplain formed upon both, is sufficient basis for the conclusion that the mountain-making movements were completed with the formation of the western Andes. From that time on, the history of both orographic systems is written in terms of erosion cycles whose development to different stages—the first to completion, the second to maturity of form, and the third but fairly begun—supplies us at once with the full means for topographic correlation. The drainage features of southeastern Bolivia unite with the topographic features to indicate that, whatever the nature of the deformations that accompanied the regional uplift of the peneplain, the peneplain was only developed after the orogenic movements had occurred which involved the red Cretaceous sandstones, for these are indicated by Hoek to "lie concordantly" with respect to the older series of rocks, and are involved with them in the same series of folds. The drainage relations support this view fully. The superposed drainage which cuts across hard and soft, across Silurian and Cretaceous alike, and is directed regardless of the structural axes, clearly supports the fact already established by the topographic features, that the peneplain was developed subsequent to that orogenic movement which closed the Mesozoic era and finally excluded the sea from that part of the continent now known as the central Andes. We are therefore assured that peneplanation followed the Mesozoic era. It must have occurred some time during the Tertiary, although profound erosion and an approach to peneplanation must have occurred in the eastern Andes during the deposition of the Cretaceous and Jurassic sediments that form the western Andes. This

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* Archhelenis und Archinotis, 1907, pp. 118–119.

preparation of the eastern Andes, the more profoundly disturbed of the two systems, for participation in the base-leveling that followed the formation of the western Andes, undoubtedly accounts for the general development of the peneplain upon both orographic systems. Our whole conception of geologic time, and especially of the time required for the completion of an erosion cycle, is so vague that neither the termination of the first cycle nor the geologic age of the mature slopes of the second can be fixed with any measure, one might almost say with the least measure of certainty. If, however, the existence of the peneplain and of the mature slopes of a later cycle are once established and the age of the former determined to be later than the Cretaceous, we are prepared to accept the conclusion that however small a portion of geologic time remains, that portion can not fail to have been long enough to produce the results observed. In short, that it is our conception of geologic time and particularly that portion of it since the Mesozoic that requires adjustment.

Current Explanation.

Inasmuch as the interpretations here presented differ radically from previous ones, a brief review of current descriptions and explanations seems advisable. The descriptions of the central Andes in standard general references have this in common, that the mountain forms of both the eastern and western "ranges" (plateaus) are described solely with reference to the order of initial uplift and the degree of dissection tacitly assumed to have been accomplished in a single cycle of erosion. "The eastern ranges were folded earlier than the western ranges, where the folds are most marked."[*] "The western Cordillera is younger than the eastern Cordillera and was covered by the sea during Paleozoic and Mesozoic times, then uplifted to a great height and still further modified by eruptive material even now, in many places, in process of accumulation."[†] These serve to indicate the point concerning uplift, while the absence of any appreciation of erosion cycles is recognized by the following description, which may well serve as a type: "In this 'Bolivian Switzerland' . . . . amid a chaos of precipitous heights, detached crests, and masses, thrown together without any apparent order, it seems difficult to detect any general plan."[‡]

Another point may here be noted concerning the interpretations so far published. While all ascribe an earlier uplift to

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[*] Herbertson, A. J., The Continent of South America (The International Geography, p. 817, 1900).

[†] A free translation of Sievers, Die West Cordillera (Süd- und Mittel-Amerika, p. 390, 1903).

[‡] Keane, A. H., South America (Stanford's Compendium of Geography, p. 240, 1901).

the eastern Andes of Bolivia, no attempt is made to deal with the topographic consequences of the greater erosion which, under comparable conditions, must follow upon greater age, except to say that the greater rainfall of the eastern Andes has resulted in much deeper dissection. Now it has been shown in the preceding chapter that, as compared with the eastern Andes the western Andes are in a far younger state of topographic development; and that the uplifted and now moderately well-dissected peneplain which forms the western Andes of Bolivia was developed to a typical degree. This now deformed peneplain is the dominating fact—the topographic motif—of the landscape; and stands out much more clearly, by virtue of less dissection, than its continuation in the eastern Andes. It is this form which led Phillipi * to deny the existence of a "Cordillerenkette" in the western Andes because of the general absence of mountain character. Since Philippi's day the suggestion seems to have passed unheeded except for an occasional quotation, each new writer vying with his predecessors in the use of adjectives fitly to describe the lofty volcanoes and volcanic knots while disregarding the pedestal or platform on which they stand.

Fig. 14.

Fig. 14. Upper La Paz Valley, west of the Cordillera Real (from Conway, Geog. Journal, 1900). Disregard scale ratio; divisions express kilometers.

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* Reise durch die Wüste Atacama, 1860 (quoted by Sievers, Süd- und Mittel-Amerika, p. 381).

Such an interpretation of the central Andes as the quotations afford not only leaves wholly out of consideration the latest events in the geologic history of the region, but also disregards some of the most obvious and important elements of form. The persistence of these elements over a wide area lends to their interpretation an importance equivalent to interpretations of stratigraphic and paleontologic facts as leading to a more complete record of geologic events.

Fig. 15.

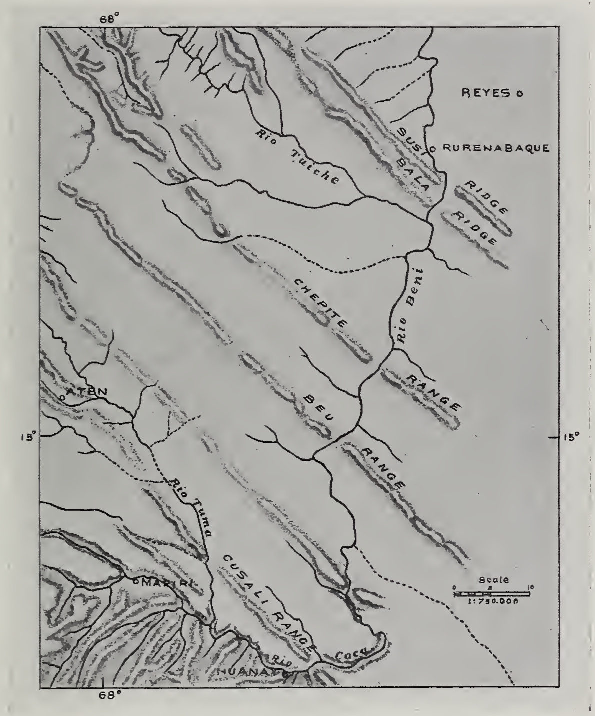

Fig. 15. A portion of Caupolican Bolivia (from Whitney, Evans, etc., Geog. Journal, 1903). Disregard scale ratio; divisions express kilometers.

Features of the First Cycle of Erosion.

The more detailed examination of the physiography of the eastern Andes of Bolivia may well begin with the great crowning range of the whole region, the Cordillera Real (fig. 14). Its structural features exhibit the solid geometry of the eastern Andes in almost diagrammatic form. It consists of a meridional axis of crystalline rocks—granites, gneisses, etc.—

and is flanked by metamorphosed sedimentary rocks—schists, slates, quartzites, and the like—of Paleozoic age (Cambrian to Lower Devonian), which dip away from the central axis.* The whole series forms an involved anticlinal with a core of granitic rock in the center. It is this granitic core which by virtue of its superior hardness gives rise to the celebrated line of lofty peaks running from Ancohuma to Illimani. Fifty miles northeast of the main axis thus outlined are the Cusali mountains (fig. 15), whose trend parallels that of the Cordillera Real. They are composed of slates, sandstones and limestones of Paleozoic age. For nearly another fifty miles are similar parallel ranges of sandstone which terminate at the Bali-Susi range, the last of the Andes mountains toward the northeast.† Beyond is the great basin of the Amazon, which at even this far inland point is but seven hundred feet above the level of the sea. The Mesozoic sediments which form these outlying ranges are either unaltered or but slightly altered; and neither in structure nor physical condition do they constitute an integral portion of the Cordillera Real.

Southward across the La Paz valley the axis of the Cordillera Real is continued in the Nevadas de Araca, Nevadas de Quimsa Cruz, and Nevadas de Vera Cruz (sometimes erroneously called the Santa Vela Cruz). These form a line of heights as definite in trend and structure as the Cordillera Real and continue the definite features of the latter southward for nearly fifty miles. They are described by Steinmann and Hoek as the direct extension of Illimani, not only as to geologic but also as to geographic character.‡ No volcanic material is found in either of the mountain groups indicated. The lofty snow-covered peaks are not a line of extinct volcanoes, but a central core of highly resistant rock whose superior hardness and greater initial elevation have preserved it from the ultimate effects of the great denudation elsewhere recognized.

The baseleveled surface developed about the western border of the Cordillera Real can be clearly identified from El Cumbre, north of La Paz. Looking south, southeast and southwest from this position (about 13,000 ft. elevation), one sees in the foreground the long slopes of the ampitheatral valley head (in which lies the city of La Paz) descending to the valley floor. In the middle distance, fig. 16, is the upper edge of the valley, descending to the right as the piedmont alluvial

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* Sievers, W., Süd- und Mittel-Amerika, pp. 381, 382, 1903.

† Expedition to Caupolican Bolivia, 1901–1902, by J. W. Evans (Geog. Jour., vol. xxii, p. 631, 1903).

‡ Erläuterung zur Routenkarte der Expedition Steinmann, Hoek, v. Bistran, in den Anden von Bolivien, 1903–4 (Petr. Geogr. Mitteilungen, Heft 1, p. 16, 1906).

slope on the margin of the great interior basin of Bolivia, descending to the left in correspondence with the gradient of the valley of the La Paz river. In the background is the even-crested platform, or plateau, whose remarkable topographic character is only appreciated when one realizes how exceedingly complex is the structure upon which the relatively simple physiographic outlines are developed. The material of the right middle distance is soft alluvium, but the material of the background is metamorphosed sedimentaries, extremely hard quartzites, sandstones and schists of Silurian, Devonian and Carboniferous age. An extension to the right of that part of the sketch which represents the alluvium would bring one to a smooth-floored basin, the Titicaca-Poopó depression; a similar extension, to the right, of the hard rocks of the right background would lead to the fault scarp which constitutes the western edge of the eastern plateau. Extended to the left the sketch would represent the residual masses which constitute a true mountain chain, the Cordillera Real, and the line of Nevadas which continue southeast beyond the La Paz valley. The elevation of the uplifted peneplain is here about 15,000 to 16,000 ft. It continues south and southeast at about this elevation, and the photograph, fig. 17, shows its development near the village of Araca, southeast of Illimani. The view looks northwest and presents with diagrammatic clearness the physiographic key to the whole region—a baseleveled surface now uplifted to form a plateau which is surmounted by residual peaks and ranges. The photograph (fig. 18) represents similar features along the western base of the Cordillera Real as seen from the town of Viachi, thirteen miles west of La Paz. The foreground is alluvium, the residual range is in the background and in an intermediate position is the rock platform, the now uplifted baselevel of erosion of a former cycle.

FIG. 16.

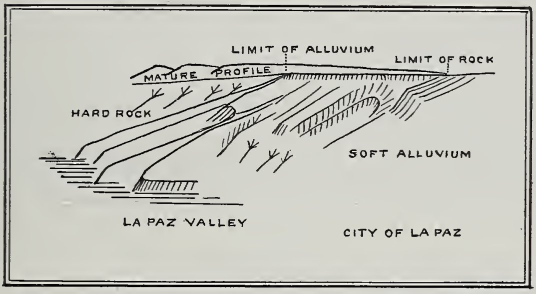

FIG. 16. Southern portion of La Paz valley from north of the city of La Paz.

From Lake Titicaca the same feature of a plane surface truncating complex structure may be observed. Fig. 19 illustrates the topographic features displayed north of the lake (west of the residuals). A similar physiographic development was observed

Fig. 17.

Fig. 17. View of Illimani and plateau (left) looking northwest from Araca.

Fig. 18.

Fig. 18. The alti-plano (high plateau) of Bolivia looking east from Viachi. The Cordillera Real in the background.

as far north as Cuzco, Peru. Photographs of the Cerro de Pasco region seem to indicate, together with reports upon the complex structure of the region, an identical history. Considering the wide range of observations and the excellent development of the feature of baseleveling, its importance at once becomes evident. Within the mountainous or residual mass one has the utmost wildness of mountain form—pinnacles, needles and crags developed upon the highly complex schists and gneisses whose upturned edges are cleaved by the swift snow-fed streams. The wildness and beauty of the scenery are brought out by fig. 20, a photograph representing Alpine features within the Nevadas de Araca.

Fig. 19.

Fig. 19. Eastern end of Lake Titicaca, with dissected plateau-remnant in the background.

To describe each separate locality where the now uplifted and dissected peneplain was identified, would be essentially but a repetition of the descriptions already given. Near Huynuni, 15,500 ft. above sea level and 500 ft. above the tin mines of that place, a splendid view to the south and southwest was obtained, and no one could fail to be astonished at the perfection of its development there. At the Abra Puca-Puca and Abra de Malaga, northeast of Cochabamba, fig. 21, the view includes a great sweep of country to the south and southeast toward Sucre; and as far as the eye can reach the even sky-line denotes how extensive is the development of the peneplain in this direction; while the same great stretch of lofty plateau, scarcely broken by residual ranges of only comparatively slight extent, is viewed at 14,000 ft. from the summit of the pass east of Pretoria Station, on the coach-road between Oruro and Cochabamba.

Before considering further the physiography of the eastern Andes, it is well to recall the main facts of the physiography of the western Andes that are correlated with those of the eastern Andes. It will be remembered that three cycles of erosion are found to have occurred (see Part I). The first may be called the great denudation, when a widespread baselevel of erosion was developed and above which only occasional peaks and ranges were able to survive because of superior hardness or advantage of position. Hard and soft rocks, simple and complex structures, high and low masses, save for the exceptions noted, were brought down to one common level but little above the sea. This is the great dominating topographic fact of the region, the organizing principle of the physiography. It represents a time interval of great length. Marine sediments younger than the Tertiary are nowhere found in the central Andine region, except in a very narrow zone near the sea in northern Chile (Eocene and doubtful Miocene). Elsewhere only terrestrial deposits occur. Even the Eocene deposits represent very limited invasions of the sea in the area now known as the coastal plateau. We have here an old land area long denuded and brought at last to a baseleveled condition. What the age of this peneplain is it seems now impossible to say. It appears from the paleontologic record to have suffered its chief deformation in the Tertiary, and if this inference be correct we have between South America and North America a very striking parallelism of topographic development.

The uplifts to which the eastern and western Andes are commonly accredited are thus seen to have little to do with the present elements of mountain form there displayed. Initial topographic irregularities responsive to structural conditions were largely obliterated; and the orogenic movements could only be said to be physiographically important as they occasionally determined the foci of those residual heights which survived the great denudation. It must, therefore, be emphatically stated that the central Andes as we know them to-day are the direct products of orogeny. The parallel ranges now observed, say between Sucre and La Paz, are not, in general, the axes of first disturbance. They are the products of revived erosion acting subsequent to a period in which the initial orographic features were largely destroyed.

Fig. 20.

Fig. 20. The Nevadas de Araca, southwest of La Paz.

Fig. 21.

Fig. 21. Map of the Cochabamba region (from Steinmann, Petr. Mitth., Heft 1, 1906). Disregard scale ratio.

Features of the Second and Third Erosion Cycles.

The deformation whereby the peneplain once existing here was uplifted was epeirogenic in nature, and affected the entire central Andine region. But the first uplift did not bring the country to the level at which we now find it. Intermediate between the present level of erosion and the peneplain we find another cycle expressed. In it the slopes were in general developed to the point of maturity, and neither the completeness of development of the peneplain on the one hand, nor the remarkable activity of erosion in the eastern Andes on the other, overshadows the field expression of these mature slopes, either in areal extent or in perfection of development. A later and second uplift once more encouraged the dissecting streams with the result that both the uplifted peneplain of the first cycle and the mature slopes of the second cycle are fast disappearing under vigorous stream attack. The most recent episode in the region is glaciation, which has, in some places, partially refilled the valleys with alluvium, and softened the once sharper outlines of the valley forms.

Fig. 22.

Fig. 22.—Graded, waste-cloaked, undissected slopes of maturity near Colomi, Bolivia, northeast of Cochabamba.

The most striking development of mature slopes observed was at Colomi (fig. 22) in a mountain valley about half way between Sacaba and Inca Corral, about thirty miles northeast of Cochabamba. The photograph represents the headwater section of a small tributary of the Juntas, a river which combines with the San Antonio to form the Chaparé at the eastern base of the Andes. Standing upon the farthest ridge in the left background and looking still further in the direction of the view (E), one would see deep dissection and partial obliteration of the mature slopes there developed, because of the greater rainfall there and greater proximity to the plains whose low altitude constitute them virtually a baselevel of erosion. The mature slopes of fig. 22 are preserved because of greater distance from the plains. The streams beyond the ridge indicated have a direct course of about fifty miles to the plains, and the rock in which their courses are cut is soft sandstone and shale; the stream draining the valley of fig. 22 has a roundabout course fully twice as long, and is held up throughout the first fifty miles by hard slates and quartzite schists. An analysis of the slopes of the figure leads one to appreciate how long an interval of time they represent between the formation of the peneplain above them and the deep dissection now elsewhere in progress and soon to be expressed in this valley also. Geologic structure is here unexpressed to a degree not less great than in the case of the baseleveled surface above. The more resistant quartzites and the less resistant slates, and the most variable dips, are all alike brought to a uniform slope expression. A heavy sheet of loose waste cloaks the rock beneath and outcrops are, for the most part, concealed. The smooth catenary curves of opposite slopes from hilltop to adjacent hilltop scarcely need description, so well organized do they appear in the photograph. In fact, organization is the keynote of the landscape hereabouts. The orderly arrangement of slopes, the continuity of the waste cover, the regular gradient of streams and valley floors, the complete subjugation of rocks of varying hardness, all alike attest the perfection of mature topographic development. Every element thus far described is contrary to the supposition of but one cycle of erosion inaugurated by one uplift. These slopes are not produced by the present drainage; they are being destroyed by it, or, as here, are about to be destroyed by it. Only ten miles down the valley, stream incision is already accomplished and hastened waste removal is disturbing the delicate organization of slopes, renewing the rock outcrops and causing the uneven expression of hard and soft rock. It requires long-continued erosion at a much less elevation than that at which the region stands to-day to produce by weathering and stream erosion such a smooth perfection of maturity. A second profound uplift inaugurated a third cycle of erosion, the one just begun, in which the very heart of the plateau and the residual mountains is being attacked by the torrential streams.

A comparison with the conditions in the Maritime Andes is important at this point to estimate the correspondence of development there, to reënforce the earlier statement that the first mountains of the region were all but obliterated, and to show that broad regional uplift, not orogenic movement, is responsible for the present loftiness of the central Andine tableland. Fig. 12 represents the view looking southwest near the pass at Crucero Alto on the railway line from Lake Titicaca to Arequipa in southern Peru. The camera is at about 14,400 ft. The description applied to the preceding view could be applied word for word to this view. All elements of form and structure in the two are comparable, except that the greater altitude of the camera in the latter photograph brings the level of the now dissected peneplain into the view and renders both cycles appreciable at a single glance.

A striking fact is the occurrence of the mature slopes right up to many of the divides near the western border of the eastern plateau. This is admirably shown on the coach-road from Oruro to Cochabamba, where the waste-cloaked valley heads are thoroughly organized with respect to the drainage. It is only some distance down valley that the dissection due to the last uplift is topographically expressed.

The disappearance of the slopes of maturity on approach to the eastern edge of the Andes is not less marked than the similar disappearance of the even-crested upland in this direction. Both alike are broken down by the terrific dissection of the mountain torrents that in many places descend 12,000 and 13,000 ft. in less than 75 miles, or with an average gradient of over 150 ft. per mile. The mature slopes in their final expression eastward appear as skeleton shoulders upon the valley sides, a typical occurrence being on the trail a few hours' ride north of Inca Corral.

The most interesting expression of the slopes of maturity is not, however, their perfect development in regions in which by virtue of favorable position they are not preserved. It is their persistent occurrence in localities now undergoing vigorous dissection that gives strongest support to the explanation based upon three cycles of erosion. Unfortunately, the natural limitations of a camera did not make it possible to secure a photograph in which all the elements of form characteristic of the three cycles were expressed in a single view. Too great a vertical range exists in the position of the three planes of erosion to make their common expression possible from a single position. The two localities selected are among a list of at least a dozen and choice among the list is difficult because of the similarity of the views and descriptions. All about Cochabamba and on the way to the divide toward Oruro, in the Cliza basin, in southern Peru, between Lake Titicaca and Cuzco, north of Inca Corral, in each one the same relationship between slopes exists as may be found in all the others. The two localities described below, Cliza, and the upper Urubamba valley in southern Peru, are farthest apart (475 miles in a straight line), the one in the eastern Andes, the other in the western Andes, and they will therefore serve to show, not only the correspondence of features and development thus far described, but also the correspondence of development between the eastern and western Andes.

The Cliza basin lies due southeast of Cochabamba (see map, fig. 21). It is enclosed by a rim of "cerros" or hills and is drained by the Cliza and Arani rivers, headwater tributaries of the Rio Grande, one of the major streams of Bolivia. The Cochabamba and Cliza basins are alike in consisting of Devonian sandstones rimmed about by Silurian quartzites and schists. A deep accumulation of alluvium is found on the floors of both basins. Both are drained by outlet streams whose old rock-cut and gravel-strewn terraces several hundred feet above the present levels of the streams at the narrow outlets of the basins represent the level of the drainage at the close of the second cycle of development, during which the slopes of maturity were formed. These terraces are particularly well developed five miles west of Arcaji, in the narrow gap through which the basin waters are discharged. About the margins of both basins the slopes have the appearance of fig. 23. The sketch is traced from a field drawing made from a point near the center of the basin looking north by west at the edge of the surrounding hills, west of the village of San Benito. Table-topped spurs descend from the broad crest of the rim (800 to 1500 ft. above the basin floor) by gentle

Fig. 23.

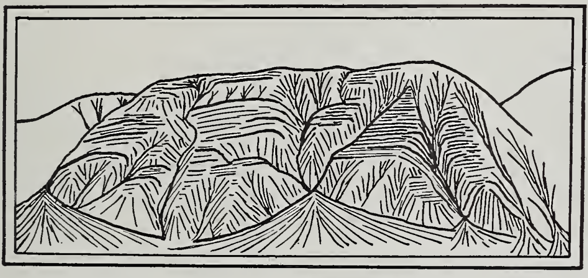

Fig. 23. Flat-topped spurs on northern border of Cliza basin, Bolivia.

gradients; and all spurs terminate in scarped fronts partially modified in outline by the huge and widely extended alluvial fans formed at the mouth of each deep-cut ravine. The flat-topped appearance of the spurs is very striking indeed and compels attention in every view from the pass of Puca-Puca to the Tunari of Cochabamba and about the whole Cliza basin. The mature profile is easily recognizable, though it is fast being destroyed by vigorous stream dissection. The margin of the basin exhibits a progressively greater amount of dissection with approach to the outlet, where the maximum incision of the outlet stream is perhaps 150 ft.

Fig. 24.

Fig. 24. Slope relationship in the Urubamba valley near Cuzco, Peru.

The valley of Urubamba, fig. 24, near Cuzco, has features very closely resembling those of the Cliza and Cochabamba basins, save for their formation on a much larger scale. The interstream areas have mountainous instead of spur proportions; the frontal scarps terminating the mature slopes are nearly two thousand feet high; the ravines are gorges or canyons; and the alluvial fans at the canyon mouths are sometimes several miles wide.

A physiographic interpretation of the forms of the eastern Andes must include attention to the valley and basin filling which is everywhere so prominent. A period of deep dissection distinctly below the level of the present drainage was followed by a period of alluviation, of partial valley filling. In spite of the dissection of mature slopes everywhere so prominent, the streams of many of the basins and valleys are not flowing upon rock but upon alluvium. An episode has occurred which for a time greatly decreased the dissection of the lower slopes. That episode is glaciation and its effects are now expressed by moraines, hanging valleys, striated surfaces, and valley-head cirques in the mountains; and by alluvium in the basins and valleys.* At present the streams are actively removing the alluvium of the valley floors and deeply trenching the alluvial fans of the valley sides. The map of a three-mile stretch of the Cliza river, fig. 25, likewise shows dissection by the succession of terraces bordering the basin streams, and due to the normal sidewise swinging of the river in the down-cutting accomplished since the glacial period. The sketch, fig. 26, shows typical relationships of uppermost peneplain, lower mature slopes, later dissection, partial valley filling, and the renewed dissection of post-glacial time, the dissection now in progress.

Fig. 25.

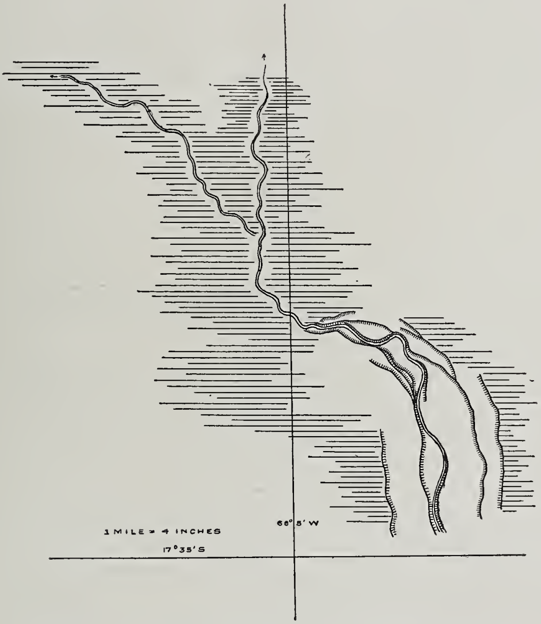

Fig. 25. Cliza river and terraces at Cliza, Bolivia.

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* A paper on "The Glaciation of the Central Andes" will be published elsewhere at an early date.

The assignment of a common origin to the now deformed peneplain of the eastern and western Andes, as expressed in the discordance between complex structures and flat-topped plateaus common to both, demands attention to certain parts of the great interior basin of western Bolivia. This flat-floored basin was explained (Part I) as primarily the product of a depressed block of the uplifted peneplain, and its borders as fault scarps. The time of origin of the basin is established by reference to the slopes already described. The uplifted peneplain remnants or the plateau tops terminate abruptly all about the rim of the basin. Several of the views already noted (Huynuni, the pass of Apacheta, etc.) are either within or almost within sight of the western border of the eastern plateau. This abrupt termination of a well-developed base-leveled surface indicates that its further extension has been faulted down, even if more direct evidence of faulting were not available. We are therefore assured that the basin was not in existence as an enclosed tract with high bordering scarps at the time that the development of the peneplain was completed, although it may well have existed as a valley or as an extremely shallow basin. The Mesozoic invasions of the sea were carried inland to this region, but no marine Tertiary is found here.

Fig. 26.

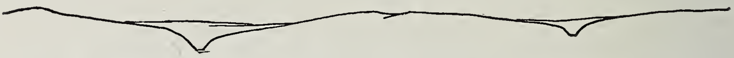

Fig. 26. Sketch showing three-cycle features prevalent throughout most of the Central Andes.

In contrast to the topographic discordance presented at the rim of the great interior basin is the correspondence of development between scarps and bordering basin in the second cycle of development, which advanced to the point of maturity. Fig. 12, in the Maritime Andes, shows a region which is organized with respect to the interior basin, and everywhere along the coach-road from Oruro to La Paz we remarked the thoroughly subdued slopes of the hills and plateau scarps. Oftentimes the structure beneath the thin waste cover shows through in slight corrugations, but in no place has such structure any important expression in the topography. The slope formed upon the dip of the schists and slates are scarcely more gentle or regular than those formed across the outcropping edges of the strata. No sudden break either in slope arrangement or stream gradients marks the debouchure of the main tributary valleys. We are obliged to conclude that the epeirogenic movement which deformed the peneplain was accompanied by block-faulting which formed the interior basin and that no significant amount of further faulting has occurred to mar the nice relation of slopes and grades which are the product of the second cycle of erosion. The second uplift, whereby the third and present cycle of erosion was inaugurated, is topographically unexpressed in the interior basin. Its self-contained character, in common with the great interior basins of all desert regions, removes it from the immediate effects of uplift. Its floor is a local baselevel of erosion. Therefore, while expressing the forms of maturity, it does not represent those of recent dissection. In fact, we may say that the second cycle of erosion is here still in progress, the slopes are becoming gentler and flatter, and in the absence of local tectonic movements the cycle may progress much nearer completion. The formation of a locally baseleveled area is, however, imperilled by the vigorous attack of the neighboring streams outside the basin,—the La Paz, Rio Grande, and Pilcomayo. These now head near the border of the basin and will eventually tap it if existing conditions of relief and rainfall are indefinitely prolonged.

In the non-glaciated parts, on the eastern border of the Andes, the slopes are not generally graded in the drainage systems tributary to the Atlantic. The last uplift was apparently sudden and undoubtedly pronounced and the eastern edge of the eastern Andes is a well-defined fault scarp 1,000–4,000 feet in height. The plains at the foot of the scarp are less than a thousand feet above sealevel. High plateaus and residual mountains are near low plains and have led to enormous and rapid dissection. The jaggedness, insecurity, and unorganized character of the valley and "mountain" forms of this eastern section are its most conspicuous features below the limit of glacial action (8,500 ft. more or less). The valleys generally have a sharp V profile. The exceptions are explained by structural conditions, in every case examined in detail. Dissection has not yet advanced to a maximum in the western half of the eastern plateau, hence in this half the graded and relatively flat slopes of the previous (second) cycle dominate; in the eastern section, as a consequence of the great dissection caused by rapid and great uplift and well-watered slopes, well-defined hanging lateral valleys occur abundantly below the limit of glacial action. This is one of the most interesting of the physiographic results of our work in the eastern Andes. We had not expected to see the condition at all, to say nothing of seeing it so generally developed. It was particularly interesting because one rides in a single day from a splendidly glaciated region with all the "discordant" features diagrammatically developed to a region where the extraordinarily rapid normal dissection had produced equivalent discordances, *equivalent* but not *similar.* The distinctive features of the hanging valleys of glaciated regions are as unlike those due to normal but super-vigorous erosion as could possibly be imagined, save for this one quality of discordant junction of tributary and master stream.

The distribution of these hanging tributaries, indeed in large measure their very existence, is controlled by geologic structure. Stream B, fig. 27, is a hanging lateral in the Juntas valley twenty miles within the eastern border of the Andes. Its small tributaries above X are cut in soft shales. After running two or three miles or more in the shale belt, they turn through slate and quartzite of superior hardness which dips often as steeply as 50°, and occasionally 60°. A waterfall or a series of waterfalls occurs down the dip of slate or quartzite. The hanging part of the tributary valley upheld by the thick layer of highly resistant schist is, in some cases, 1000 to 2000 ft. above the bottom of the main valley. One is scarcely ever out of sight of one of these in a whole day's ride. On the other side of the valley the rapid erosion of the master valley, itself in a belt of shales, has under-cut the rock so rapidly that the tributaries are cut off, as Russell has described certain similar valley tributaries.* Exceedingly complex structure, strong dip, and sharp alternations of hard and soft rock com-

Fig. 27.

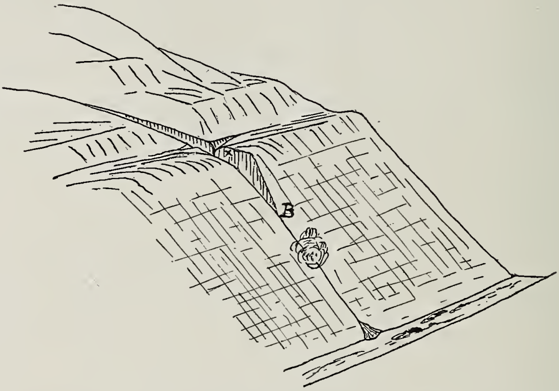

Fig. 27. Sketch of hanging valley relationships in the Juntas valley, Eastern Bolivia.

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*Bull. Geol. Soc. Am., vol. xvi, pp. 75-90, 1905.

bine with rapid uplift and corresponding deep dissection to make the feature a general one in the eastern Andes region.

The strikingly general occurrence of hanging valleys in this region constitutes them a type, and hanging valleys cannot therefore be said to be peculiar to glaciated regions. But it is the form of the valleys and the geologic structure that with the hanging quality must determine the explanation. No one could mistake the V-shaped valley at X, fig. 27, for a glaciated valley. Nor can one find here any equivalent for the special features of glaciated regions even if the other more obvious marks of glaciation were removed by post-glacial stream erosion.

Finally the eastern Andes are, after all, peculiar in the sense that few regions have the particular combinations of rapid and great uplift, deep dissection and strong and sudden alternations of hard and soft rock there exhibited. The regions in which these conditioning factors are absent do not have hanging valleys except where glaciation has influenced the development of slopes. No one should misinterpret these two kinds of valleys merely because they have this in common, that they are hanging with respect to the master stream. In the assemblage of detailed characters no other likeness between the two types is discernible.

The foregoing interpretation of the topography of the eastern Andes, the great eastern plateau of Bolivia, has peculiarly interesting support in the drainage relations that are characteristic of the entire region from Caupolican Bolivia to the southeastern border of the Republic at Tarija, the latter region as described by Hoek.* The drainage is established upon the surface in curious disregard of the structure. Forty miles southwest of Tarija, the San Juan and Honda rivers, fig. 28, flow northwest across the folded Silurian and Cretaceous sandstones and Silurian schists in courses that are utterly regardless of the structure. Even the small Rupasco tributary of the San Juan, after following a northward course in a synclinal valley, turns west against the dip of the more resistant schists and crosses one limb of the next anticlinal before joining the master stream. The Tarija river itself is represented upon Steinmann's map† as crossing four ridges of rock, varying from Silurian schists to Cretaceous sandstones, in a distance of twenty miles. In fact the most striking physiographic feature of this map is the persistent way in which the drainage cuts across ridge after ridge of rock of all degrees of hardness, dip,

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* Ante.

† Erläuterung zur Routenkarte der Expedition Steinmann, Hoek, v. Bistram in der Anden von Boliven, 1903-1904 (Petr. Geogr. Mitteilungen, Heft 1, 1906).

and trend. This is especially well-marked in the region north of Sucre, between Cochabamba and Oruro, where it was observed by the writer, and again north of Oruro from Caracollo to Colquiri. Any explanation of the drainage must therefore begin with the larger members of the stream systems directed in somewhat the same way that they are arranged to-day. The original drainage produced by the initial folding of the mountains, a drainage sympathetic with respect to anticlines and synclines of considerable regularity and great size, has been completely modified. To-day, not only are the axes of the major streams everywhere directed across these mountain axes, but even the tributaries that drain the lesser areas are not infrequently in anticlinal valleys, though this arrangement is not general because of the small extent of soft rock found in the series uncovered by the erosion of the folds.

Fig. 28.

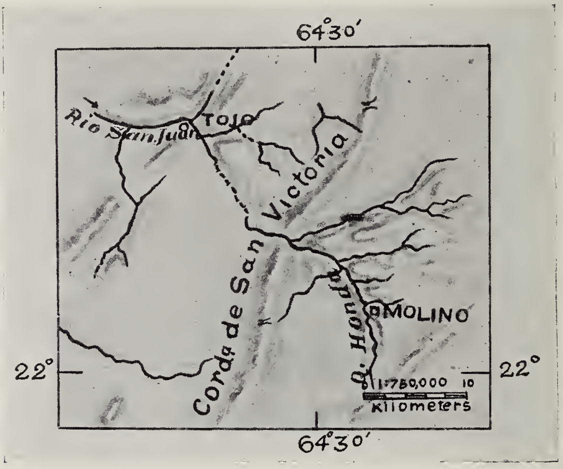

Fig. 28. Map of the Tojo region, southwest of Tarija, Bolivia. (From Steinmann, as in fig. 21.) Disregard scale ratio.

Identically similar features are expressed in the region northeast of the Cordillera Real. (Fig. 15.) The streams draining toward the northeast cut straight across the foot-hill region of northwest trending ridges, and must likewise have gained their courses before ridges, as we know them to-day, appeared. Evans* assigns the stream courses of Caupolican Bolivia to a remote period "before the evolution of the present features of the country" and the present unsympathetic relation of streams to structure as being brought about by subsequent "earth

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*Expedition to Caupolican Bolivia, 1901-1902 (Geog. Jour., vol. xxii, 1903).

movements and erosive action". We have here the only hint in the whole literature of a feature as general as it is important and one which harmonizes so well with the conclusions reached along other lines that it lends to it a very high degree of credibility.

The baseleveling of this whole region supplies the condition which is required to explain the streams arrangements. The existence of the peneplain is well established and its existence meant a high degree of discordance, not only between surface and structure, but also between drainage lines and mountain axes. Upon such a baseleveled surface streams flow with a minimum correspondence between their ultimate courses and their consequent courses as determined by the initial outlines of the folds. The warping of a baseleveled surface effects further changes, which, as the warping may be entirely inharmonious with respect to the orogenic movements, may still further disarrange the drainage systems and cause at last an entirely inharmonious relation between streams and structures. The warping has the further effect of renewing dissection and by such renewal exposing the once buried rock to the effects of differential erosion. The rejuvenated streams begin anew to carve out mountain range and valley as the dissection of the softer rock by tributary streams follows upon the transverse incision of the master streams. There thus comes about precisely that arrangement of streams that is exhibited in the eastern plateau to-day. Master streams flow regardless of the mountain ranges, so called. Some of the smaller tributaries were developed along belts of weaker rock subsequent to the uplift of the region; others were developed in harmony with the original mountain structures.

Perhaps the most interesting drainage feature of the whole region is the course of the La Paz river, concerning which there has been a great deal of speculation and an equal amount of erroneous explanation. Its striking transection of the greatest mountain chain of Bolivia (fig. 14), its invasion of the great interior basin of Bolivia and the soft material in which it is cutting in the headwater region to-day, have drawn the attention of every student of Bolivian geography. A widely current explanation is that at one time Lake Titicaca discharged eastward through the gorge of the La Paz river, but that this gorge was blocked by debris from the surrounding mountains, thus giving an enclosed quality to the Titicaca system. The explanation would be called absurd, were it not for its advancement by well-known geographers. It is, therefore, necessary to say that the highest strand line of the old lake that once existed here is over a thousand feet below the level of the edge of the basin drained by the La Paz river, and that the lake was formed subsequent to the deposition of the alluvium now found there. There has never been a lake in the region except this glacial lake, for the deposits which the La Paz river is dissecting all about the city are distinctly not lake deposits. They are the coarsest alluvium, the sort of material that mountain torrents carry, only roughly sorted and bearing all the marks of stream and not lake deposition. The clay beds found intercalated with these coarse deposits, and used for brick-making, are glacial clays. They are pebbly, impure, local, and irregular in occurrence, with nothing in their structure or position to warrant the hypothesis of deposition in the waters of a lake. Two other hypotheses have been put forward in explanation of the course of the La Paz river. The first is that the river is antecedent in origin, having gained its course upon an initial surface previous to the uplift of the Cordillera Real, and that it has persisted in it during the slow upheaval of mountains in its path. Two objections stand in the way of the acceptance of this view. A stream as short as that part of the La Paz west of the Cordillera Real (twenty or thirty miles), as Conway has pointed out,* could scarcely withstand the tremendous obstacles which these mountains afford. Nevertheless, if the uplift were slow enough even this great task might be done by a stream as small as the La Paz. In this event, however, we should look for one of two results. A stream that has persisted in a given course since the close of the Paleozoic must have its relations to rock structure and to adjacent divides well established. We cannot grant to such a stream to-day an unstable headwater condition. Now it is the most striking characteristic of the La Paz that its headwater section is undergoing the most vigorous dissection and has been cut back miles within glacial and post-glacial time. If we restore that part of its course recently cut away, we have a stream that is even shorter than the already very short course indicated above; in other words, we have a mountain torrent, and it is precisely this sort of a stream that we conclude that the La Paz must have been in this region previous to the uplift of the peneplain so excellently preserved about the western base of the Cordillera Real. The tremendous advantages of heavy precipitation and excessive gradients of those streams that flow eastward off the flanks of the Cordillera Real and the strong warping in this direction of the old peneplain has given these streams exceptional advantages over those tributary to the interior basin. The consequence is not alone expressed in the La Paz. On Steinmann's map the Sayacuira is shown crossing this same mountain axis south of the Sierra Vera Cruz, although here the height of the range is, to be sure, very much

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* Climbing and Exploration in the Bolivian Andes, pp. 126–128, 1901.

lower than in the path of the La Paz. The Mapiri has eaten its way back toward Lake Titicaca until now a divide but 1500 ft. high separates it from the Titicaca basin; and in a geologic sense the capture of the Titicaca waters is imminent from this direction to a degree but slightly less marked than in the case of the La Paz. Further interest attaches to these future changes in the disposition of the basin waters because of the transition that is now in progress in the Titicaca basin itself. Its waters are gradually receding from its shores (fig. 19), and the discharge of the Desaguadero, its outlet, is likewise decreasing. The climatic change which this expresses is steadily progressing and, if continued, will lead to the complete isolation of the Titicaca drainage. The lake will then become salt for a period; but it will again become fresh when capture from the east or north supplies it again with an outlet. These changes will occur in a short space of time geologically speaking, and will *undoubtedly* occur if the forces now in operation here are continued in their present direction.

Further support is given this view by the direction in which the headwater attack is taking place. The La Paz tributaries west of the Cordillera Real are all working most vigorously in the piedmont deposits that front the range. The courses are arranged in part regardless of the piedmont, in part in strict conformity to it. The slopes of the piedmont are everywhere arranged regardless of the main drainage. On the south side of the La Paz amphitheatre one looks in vain for a slope towards the amphitheatre. The drainage of the interior basin begins at the very lip of the amphitheatre and runs away from it. On the other side the mountain streams descend steeply from the Cordillera Real and then turn in semi-circular courses (fig. 14) toward the main axis of the La Paz valley. The structure lines within the detrital material do not dip down the present inclines of the valley head, but in a contrary direction. We must conclude from this evidence that the piedmont was formed long before the La Paz river headed west of the main range and that the present course of the river is due to headward gnawing in very recent geologic time, a process still is active operation.

It is important to note that the rainfall and other conditions are here very special indeed, and that a similar explanation cannot be assigned to the other rivers of the plateau whose courses are out of sympathy with the structure. For example, the streams that cut across the old mountain axes between Cochabamba and Oruro are well within the eastern divides that bar the rain-bearing winds. They occur in a dry region and, furthermore, one in which the warping of the peneplain has been distinctly less marked than in the region east of the

Cordillera Real. They are therefore superposed courses which were developed upon the old peneplain when what is now ridge and valley stood at a common level. The uplift whereby the second cycle of erosion was inaugurated was a broad uplift, the streams incised their valleys slowly within the heart of the plateau although on its borders dissection progressed with extreme rapidity because of the marked break within short distances between low plain and strongly uplifted plateau. Only the weaker tributaries have had their courses modified. These have developed along the belts of weaker rock and are arranged in consequence in strikingly linear courses at right angles to those of the master streams. The "total-eindruck" is strikingly like that derived from a study of our own Appalachian drainage system where the trellised pattern of the drainage bears evidence of the two-cycle origin of the members of each drainage system.

A striking feature, and one that gives a high degree of conclusiveness to the interpretations here offered, is the occurrence of such large blocks of undissected remnants of the peneplain at high levels. The reconstruction of an old surface in many instances depends solely upon the plane of the hill top levels and its discordance with respect to structure; in the present case the surface itself, practically undissected over wide areas, affords a convincing quality to the interpretation. The relatively slight degree of dissection that the peneplain remnants of the western Andes display in so many places is owing in small part to their favorable situation with respect to the runoff of the mountains (or the lack of lofty mountains) behind them, and in larger part to the extreme aridity of the climate. The existence of the peneplain, and the slight extent of residual mountains upon it, led to a much more even distribution of rainfall than is at present the case. At no time in their history were the Andes so high as they are to-day; and at no time were the regional climatic contrasts so sharply marked and extreme as they are to-day. These climatic contrasts were offered at the close of the first deformative period in which the peneplain of the great denudation cycle was elevated and have been strengthened by the even greater uplift which closed the second cycle of erosion. Contrasts in degree of dissection in the cycles since the great denudation have therefore been gaining in strength, and in the cycle of vigorous dissection recently inaugurated these are at a maximum. In the western Andes are the relatively undissected plateau remnants; the eastern Andes show upon their margin some of the profoundest dissection that can be found upon the earth to-day.

Geological Department,
Yale University.

Art. XXXVIII.—*A New Species of Teleoceras from the Miocene of Nebraska;* by Theodore F. Olcott.

Teleoceras minor, sp. nov.

This small rhinoceros from the Loup Fork beds of the Niobrara River Valley, Cherry Co., Nebraska, was found by me last year and represents the remains of a fully adult but not old animal. The specimen was broken into several pieces but is well preserved and consists of the occipital region and roof of a skull, the right zygomatic arch and maxilla with the grinders as far as premolar one in place. It shows a very small but unmistakable rugose spot on the median line of the frontals, as does *Teleoceras medicornutus* Osborn.* Its affinities to the genus are recognized in the laterally compressed nasals with rounded and protruding tips, the low and broad occiput, the low sagittal crest and the constricted protocone and strong crochet on the molars. The premolars are less reduced than in *T. fossiger*. In this respect the type appears to stand between *Teleoceras* and *Aphelops* with tendency towards *Teleoceras*. The alveole of premolar one indicates a small, short-rooted tooth.

The species is small, the contour of the skull is concave antro-posterially, the frontal region is flattened, the free nasals are moderately long with tips protruding 15^{mm} beyond their inferior borders, which are slightly expanded anteriorly. The superior dental series is P 4 M 3. There is a well developed crochet on all the teeth.

The protocone and hypocone are united in the partly worn premolars and enclose the median valley. The crochet is prominent on the molars and the antecrochet is strong in molar one.

Measurements.	mm
Length from end of nasals to occipital crest	430
Height from lower border of occipital condyle to summit of occipital crest	180
Transverse diameter of occiput including post-tympanic processes	260
Greatest transverse diameter of frontals	139
Narial notch to orbit	68
Length of free nasals	106
Antro-posterior diameter of molars (crown measurements)	129
Antro-posterior diameter P 2	31

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* Bull. Am. Mus. Nat. Hist., vol. xx, pp. 319–321.

Transverse diameter P 2	32
Antro-posterior diameter P 3	35
Transverse diameter P 3	43
Antro-posterior diameter P 4	38
Transverse diameter P 4	49
Antro-posterior diameter M 1	50
Transverse diameter M 1	53
Antro-posterior diameter M 2	52
Transverse diameter M 2	52

Rockville Center, L. I.
May 3, 1909.

SAMUEL WILLIAM JOHNSON.

The prominent chemist and teacher, and the most eminent figure in American agricultural chemistry, died at his home in New Haven on July 21st, 1909, in the 80th year of his age. Professor Johnson was born of Connecticut ancestry at Kingsboro, N. Y., July 3d, 1830, and spent his youth on his father's large and prosperous farm in Deer River, Lewis Co., in the same state.

His early education was obtained in the common schools and at Lowville Academy. It was at the latter institution that he became interested in scientific subjects, and his enthusiasm for chemistry led him to equip a laboratory at his home, where, guided only by his books, he pursued a systematic course in analytical chemistry—a very remarkable achievement for one so young.

At this period, when about 17 years old, his first recorded article, "On Fixing Ammonia," was published in the *Cultivator*. This was prophetic of his future career, and it was followed in later years by a great many important writings for the benefit of the farming community.

After having taught for two winters in district schools, Mr. Johnson, at the age of 18, began his long career in the teaching of science. He taught natural sciences for a year at the Flushing Institute, Long Island, and two years later he spent a winter as instructor in the same subjects at the New York State Normal School at Albany.

Meanwhile, in 1850, he had entered the Yale Scientific School, with which he was soon to be permanently connected, and studied chemistry, particularly the agricultural branch of the science, with Professors John P. Norton and Benjamin Silliman, Jr. During this period of study in New Haven, covering about eighteen months, he published two mineralogical notes in this Journal the first of his many publications here, and also wrote two articles for the *Cultivator*, the title of one of them, "Agricultural Education," being very significant of his interests at that time.

In January, 1853, he went to Germany, where he spent two years in study at Leipsic and Munich with the celebrated scientists Erdmann, Liebig, von Kobell, and Pettenkofer. During his stay in Germany he published in the *Journal für praktische Chemie* several articles and notes relating to his chemical investigations. This work was in pure chemistry, rather than on the agricultural side of it, and during his after life he took a deep interest in the strict science and made numerous contributions to it.

Leaving Germany early in 1855, he went to England and spent that summer studying with Frankland. During his stay in Europe he acted as foreign correspondent to the *Country Gentleman*, and in that capacity published a large number of articles on agriculture. It is interesting to notice that one of the earliest of these letters described the Agricultural Experiment Station at Möckern, for he was destined to devote much labor towards the establishment of such stations in the United States, and it was chiefly due to his efforts that this object was finally accomplished, at first in Connecticut.

In September, 1855, having returned to New Haven, he became chief assistant in the chemical laboratory of the Yale Scientific School. The next year, 1856, he was advanced to the position of Professor of Analytical and Agricultural Chemistry. In 1874, owing to a modification of his duties, his title was changed, in what had now become the Sheffield Scientific School, to Professor of Theoretical and Agricultural Chemistry. This position he held until 1896, when he retired as Professor Emeritus.

Professor Johnson's long connection with the Scientific School added much to the fame of that institution. His career was closely connected with those of Professors Brush and Brewer, who began their work here at nearly the same time, when the School was very small. His teaching was chiefly in the lines of analytical, theoretical, and organic chemistry, for the demand for agricultural chemistry among the students was comparatively small. He always impressed his students by his wide and profound knowledge, and attracted them by his sprightly, cheerful disposition. He was a clear, fluent and philosophical lecturer.

While his teaching and his services to agriculture absorbed much of his time and attention, Professor Johnson's chemical investigations were also important. He was particularly skillful in devising new and improved apparatus and methods of analysis. In this connection may be mentioned his device for the accurate determination of carbon dioxide, his simpler substitute for the original soda-lime used for nitrogen combustions, his apparatus for extraction with volatile solvents, and his many researches, both alone and with the coöperation of others, on the analytical determination of the important constituents of fertilizers.

His services to agriculture were especially brilliant. Besides the multitude of more or less popular contributions to agricultural periodicals, he delivered many addresses to farmers, and as early as 1859 he gave a course of lectures on agricultural chemistry at the Smithsonian Institution. In 1857 he became chemist to the Connecticut State Agricultural Society, and for several years published in its *Transactions* the results of his examination of many fertilizers, and essays upon other topics.

Shortly after the establishment of the Connecticut Agricultural Experiment Station, for which he had labored so long and earnestly, he became its Director in 1877, and acted in that capacity until 1899. In this position he was eminently successful, setting an example to the stations of the same kind which were soon established in all the other states of the Union.

He was very conspicuous in his literary activity. His voluminous writings for the agricultural press have been alluded to already, and his official reports of the Agricultural Station, published annually for more than twenty years, should also be mentioned. He edited the first American editions of Fresenius's "Qualitative" and "Quantitative Analysis," and afterwards revised the former work, supplying it with the "new system" of chemical nomenclature and symbols. He published many of the results of his scientific investigations in this Journal, and was an associate editor of it from 1863 to 1879. Particularly during the earlier years of this period, he was also a copious contributor to its department of "Scientific Intelligence."

He was the author of several books: "Peat and its Uses as a Fertilizer and Fuel," 1866; "How Crops Grow," 1868; and "How Crops Feed," 1870. One of these particularly, "How Crops Grow," a treatise on the chemical composition, structure and life of the plant, should receive special mention as a very celebrated work. It was not only received with much favor in America, but an English edition of it was published, and it was translated into German, where it was honored with a preface by Justus von Liebig. It was translated also into Russian, Swedish, Italian, and Japanese. The author published a revised and enlarged edition of this work in 1891. It is fortunate that a full bibliography of Professor Johnson, up to 1892, was prepared by himself and published in "Yale Bibliographies."

Professor Johnson's services to science were widely recognized. He was elected to membership in the National Academy of Sciences in 1866, was president of the American Chemical Society in 1878, chairman of the sub-section of Chemistry, American Association for the Advancement of Science, in 1875, associate Fellow of the American Academy of Arts and Sciences, and at one time was president of the Association of American Agricultural Colleges and Experiment Stations.

Professor Johnson married Elizabeth Erwin, daughter of George H. Blinn, of Essex, N. Y., on October 13th, 1858. She and a daughter, Mrs. Thomas B. Osborne, of New Haven, survive him.

H. L. Wells.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *A New-Method for the Determination of Iodides and Free Iodine.*—Bugarsky and Hovrath have devised a method for the determination of iodine which appears to be particularly well adapted to mineral waters and similar solutions containing small quantities of this element. It is based upon the fact that free iodine is slowly converted into iodic acid by the action of bromine, particularly at about 100°, according to the equation

$$I_2 + 5Br_2 + 6H_2O = 2HIO_3 + 10HBr.$$

The liquid to be analyzed is placed in a narrow necked flask of 100^{cc} capacity. Not more than 10 or 12 mg. of iodine should be present. The liquid, if alkaline, is acidified with sulphuric acid to such an extent that it is finally less than $\frac{1}{100}$ normal in terms of free acid. Then about 50^{cc} of saturated bromine water are added, and the flask is filled to the lower part of the neck with distilled water. The flask is then suspended in a beaker of water and this water is boiled for one hour. After this operation the contents of the flask are transferred to a capacious Erlenmeyer flask of at least 250^{cc} capacity, a little powdered pumice stone is added, and the contents of the flask are boiled very vigorously for four or five minutes to remove the bromine. The liquid is then cooled, 1 or 2 grams of potassium iodide, and sulphuric acid corresponding to about 10^{cc} of the normal solution are added, and after waiting two or three minutes the iodine set free is titrated with $\frac{1}{100}$ normal thiosulphate, using starch solution as an indicator. One-sixth of the iodine found corresponds to the amount originally present. Since commercial bromine usually contains a little iodine, this reagent should be analyzed once for all by the same method before use.

The authors have obtained extremely good results in carrying out this method with known amounts of iodine. They have found that even large amounts of chlorides and bromides do not interfere with the method, and also that such impurities as may be present in natural waters and certain medicines—nitrites, nitrates, ammonium salts and glucose—do not affect it. Even compounds of iron and manganese do not interfere if the final titration is stopped when the blue color first disappears for a moment.—*Zeitschr. anorgan. Chem.*, lxiii, 184. H. L. W.

2. *Chemical Action of the Penetrating Rays of Radium upon Water.*—It has been shown by M. Kernbaum that the radium rays which pass through glass act upon distilled water with the formation of hydrogen peroxide and the liberation of hydrogen, according to the equation $2H_2O = H_2O_2 + H_2$. In one experiment where about 0·1 g. of nearly pure radium chloride in a

sealed glass tube was allowed to act upon 30^{cc} of water for forty-one days, it was possible to determine the amount of hydrogen peroxide by titration with very dilute potassium permanganate. The hydrogen evolved was collected and measured, and it was found to be free from oxygen when the experiment was conducted with the proper precautions for the exclusion of air. The amount of energy calculated as utilized by the reaction under consideration as compared with the known amount of heat evolved by radium was 1 : 17,500 where a thicker tube was used, and 1 : 11,600 with a thinner tube. The author believes that the effect described is due entirely to the β-rays, and that the γ-rays do not take part in the reaction, for he could not produce the reaction by the action of the Röntgen rays under similar conditions.—*Comptes Rendus*, cxlix, 116. H. L. W.

3. *The Decomposition of Water by Ultra-violet Rays.*—A method for the sterilization of water, consisting in immersing in it a mercury-vapor lamp acting in a quartz tube for about a minute, has been described by Courmont and Nogier, who failed to find in water thus exposed to the ultra-violet light for a period of ten minutes any evidence of the presence of ozone or other powerful oxidizing agent. M. KERNBAUM has found, however, by extending the exposure to ten hours, that hydrogen peroxide and hydrogen are thus produced, and consequently that the action of the ultra-violet rays upon water is the same as that of the β rays from radium.—*Comptes Rendus*, cxlix, 273. H. L. W.

4. *Radio-activity of Potassium Salts.*—Campbell and MacLellan, who have studied the weak radio-activity of potassium salts, have attempted to concentrate this property by fractionation, but always with negative results. HENRIOT and VAVON, using the fractional crystallization of the chloride, repeated precipitation of the chloride with gaseous hydrochloric acid, and repeated precipitations of barium sulphate in a solution of potassium sulphate, have also failed to find any concentration, and they have thus strengthened the opinion that this radio-activity is due to potassium, and not to an unknown impurity. They have shown also that the radiation in a magnetic field behaves like a negative flow of electricity, thus identifying it as composed of β rays.—*Comptes Rendus*, cxlix, 30. H. L. W.

5. *The Cementation of Iron by Charcoal in a Vacuum.*—Conflicting views have prevailed in regard to the possibility of the absorption of carbon by iron in the absence of gases. GUILLET and GRIFFITHS have now made some careful experiments in regard to this matter, and find that when the iron wire and the sugar-charcoal have been first heated alone in a vacuum to 1000° C., there is no appreciable cementation when they are heated in contact to the same temperature. When, however, the materials are heated under powerful pressure cementation takes place slowly. They conclude that solid carbon plays an insignificant part in industrial cementation.—*Comptes Rendus*, cxlix, 125.

H. L. W.

II. GEOLOGY.

1. *The Devonian Faunas of the Northern Shan States;* by F. R. COWPER REED. Mem. Geol. Surv. India, Pal. Indica, n. ser., II, pp. 183, pls. 20, 1908.—This welcome work on the Middle Devonian faunas of Burma describes 165 forms from Padaukpin and 30 from Wetwin. About 120 species are named specifically and of these 34 are new. Corals, Bryozoa and Brachiopoda constitute the bulk of the fossils. The author also reviews all other Asiatic Devonian faunas. The majority of the species are clearly western European and of the Calceola sandalina fauna. There is nothing present to remind one of the Middle Devonian faunas of eastern North America and but little that recalls our western faunas having Euro-Asiatic connections. The Wetwin fossils remind some of the New York Portage biota, but as their preservation is not good and the fauna a small one, not much value can be placed on this slight resemblance. C. S.

2. *Osteology of the Jurassic reptile Camptosaurus, with a revision of the species of the genus, and descriptions of two new species;* by CHARLES W. GILMORE, Proc. U. S. National Museum, vol. xxxvi, pp. 197–332, with pls. 6–20 and 48 figures in the text.—This is an important contribution to our knowledge of American dinosaurs, to which subject Mr. Gilmore has devoted especial attention. After a brief historical review of the genus, Gilmore discusses at some length the osteology of Camptosaurus as shown mainly in the type specimen of *C. browni*, a new species. The generic definition follows with an alphabetical list of species. In the systematic description and revision of species, Gilmore accepts as valid all four erected by Professor Marsh, to which he adds two others, one from the Morrison and one from the Lakota. Of the four European forms referred to this genus the author admits but one, *Camptosaurus prestwichii* from the Kimmeridge clay. Camptosaurus is evidently allied to the European Iguanodon, but is a more archaic type and suggests a somewhat greater age for the beds in which it is found. Gilmore thinks that the evidence shown by the Camptosauridæ not only supports the contention that the lower members of the Morrison (Atlantosaurus Beds) are below the Wealden, but that they are of greater age than the Purbeck and possibly equivalent to the Kimmeridgian.

Two restorations of the animals are given, one, that of Professor Marsh, the other a photograph of a specimen of *Camptosaurus nanus* in the American Museum of Natural History. The former restoration is in error principally in showing too many presacral vertebræ, giving the animal too long a back.

Nothing is said of probable habits, but Mr. Gilmore is of the opinion that a quadrupedal mode of progression was the more habitual. R. S. L.

3. *The systematic relationships of certain American Arthrodires;* by L. HUSSAKOF, Bull. Amer. Mus. Nat. Hist., vol. xxvi, pp. 263–272, with pl. xlv, and 8 text figures.—In this brief paper Dr. Hussakof describes two new genera, each with but a single species, and expresses doubt as to the validity of the genus Protitanichthys of Eastman, the species of which he refers to the well-known Coccosteus. R. S. L.

4. *A revision of the Entelodontidæ;* by O. A. PETERSON. Memoirs of the Carnegie Museum, vol. iv, No. 3, 1909, pp. 41–146, with pls. liv–lxii and 80 text figures.—An admirable piece of work in which Mr. Peterson has brought together all that has been published of these swine-like creatures, enriching it with many observations of his own upon the material at Yale, the American Museum, the Carnegie Museum, and elsewhere.

The introduction is followed by a revision of genera and species, followed in turn by a history of the discovery and excavations in the famous Agate Spring fossil quarries in western Nebraska; the paper closing with a full anatomical description of the most notable specimen that these quarries have produced, the huge Dinohyus, a creature of rhinocerine bulk.

The relationships of the various genera, their distribution in space and time and an account of the probable feeding habits close the memoir. The bibliography includes 114 titles, so extensive is the literature upon this interesting group. R. S. L.

5. *A new species of Procamelus from the Upper Miocene of Montana, with notes upon Procamelus madisonius Douglass;* by EARL DOUGLASS, Ann. Carnegie Museum, Vol. 5, Nos. 2 and 3, pp. 159–165, with pls. ix–xi and two text figures.—Mr. Douglass describes briefly the skull, jaws, and cervical vertebræ, constituting the type of the new species of camel, *Procamelus elrodi*, found by him in the Lower Madison valley in Montana. The animal possessed a large skull with a relatively large braincase when compared with other species of its genus. The type skull of *Procamelus madisonius*, described by Douglass in a previous paper, is figured for the first time and the description amplified. R. S. L.

6. *Notes on the fossil mammalian genus Ptilodus with descriptions of new species;* by JAMES W. GIDLEY, Proc. U. S. Nat. Museum, Vol. xxxvi, pp. 611–626, with pl. 70 and 9 text figures.—In this important paper Mr. Gidley gives some of the results of a special expedition to the Fort Union beds of Sweet Grass county, Montana. One specimen in particular, the type of *Ptilodus gracilis* n. sp., is remarkably complete and adds greatly to our knowledge of the Allotheria or Multituberculata. Mr. Gidley's conclusions may briefly be summed up as follows:

The genus as newly defined combines the upper dentition of the supposed genus Chirox with the lower dentition of Ptilodus, thus proving the synonymy of the genera. The same is probably true of the genera Bolodon and Plagiolax.

Certain undoubted Ptilodus jaws from the Fort Union beds are probably identical with two species of Hallodon described by Professor Marsh from the Ceratops beds of Converse county, Wyoming, while other species of Ptilodus have been found in the Torrejon beds of northern New Mexico, thus giving new evidence of the close affinity, if not identity, in part at least, of these three formations. Zoölogically, Mr. Gidley would remove the Allotheria from the Prototheria, where they have been placed by certain, authors and associate them with the Diprotodont Marsupials, not as the direct forebears, but derived from a common ancestry somewhere in Jurassic or Triassic time. Finally Gidley considers these creatures as frugivorous in habit, possibly living upon small fruits and berries. R. S. L.

7. *Descriptions of two new species of Pleistocene ruminants of the genera Ovibos and Boötherium, with notes on the latter genus;* by James W. Gidley, Proc. U. S. Nat. Museum, Vol. xxxiv, pp. 681–684, with pls. lvii–lix and one text figure.—Mr. Gidley here describes two new horned ruminants from post-glacial deposits, though from widely separated localities, Michigan and Alaska, the former locality yielding the Boötherium found in association with a mastodon.

Gidley expresses the opinion that the genus Boötherium, supposed by some to be synonymous with Ovibos, the musk ox, is valid and may represent a distinct subfamily of the Bovidæ.

R. S. L.

III. Miscellaneous Scientific Intelligence.

1. *British Association for the Advancement of Science.*—The seventy-ninth annual meeting of the British Association was held at Winnipeg during the week beginning August 25. This is the fourth meeting of the series held outside of the British Isles; it was highly successful in attendance and still more in the importance of the scientific work done, notably the inaugural address of Sir Joseph Thomson, and the sectional addresses of Profs. H. E. Armstrong (Chemistry), E. W. Rutherford (Physics) and Dr. A. Smith Woodward (Geology)—see *Science* for Aug. 27, Sept. 3 et seq., also *Nature* of Aug. 26, Sept. 2, etc. Numerous excursions were held, including one extending to the Pacific Coast. Dr. T. G. Bonney will be the president of the meeting for 1910, to be held at Sheffield.

2. *Einführung in eine Philosophie des Geisteslebens;* von Professor Rudolf Eucken in Jena. Pp. 197. Leipzig, 1908 (Quelle & Meyer).

Dr. Cyrus Adler,
Librarian U. S. Nat. Museum.

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FOURTH SERIES

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NEW ARRIVAL

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A. H. PETEREIT,

81—83 Fulton Street, New York City.

FIG. 1. Vesuvius—Interior of the great crater, as seen from a cleft in the northern rim.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXIX.—*Vesuvius: Characteristics and Phenomena of the present Repose-period;* by Frank A. Perret, K.I.C., former Honorary Assistant at Royal Vesuvian Observatory. (With Plate I.)

The modern eruptive processes of this volcano show a marked periodicity. Mercalli has published a list of twelve eruptive periods* since 1700, each culminating in a paroxysm followed by a distinct interval of complete inactivity, the duration of which has varied from two to seven years, with three and a half years as an average. During these periods of repose the central conduit is obstructed, as a result of the preceding paroxysm, and the volcano assumes the solfataric condition marked externally by fumarolic emanations.

It should be noted, however, that if these repose-periods mark the end of one era of activity, they also herald the dawn of the next to come. The condition of repose is apparent and external and represents a preparatory phase which forms a part of the cycle of events. This should not be considered, therefore, as an interval of time during which the volcano is uninteresting, but rather as offering a precious opportunity for investigating the methods by which the hidden forces develop into a condition of external activity and for studying at close range the chemical and other phenomena which may serve as indices of future eruption.

Owing to the exceptional duration of the last eruptive period—1875–1906—and the violence of its culminating paroxysm, the present rest-period may be expected to be of greater than the average length and of more than ordinary interest. During the three years already elapsed the eruption of Strom-

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* G. Mercalli, "I Vulcani attivi della Terra," Ulrico Hoepli, Milan.

boli in 1907 and that of Etna in 1908, together with the Messina earthquake, have claimed attention, and I have, in addition, made several visits to the United States; it is therefore with far less than the desired thoroughness and only as time and circumstance would permit that I have been able to make those observations and studies which form the subject matter of the present paper.

For the sake of clearness I propose to treat of the characteristics and phenomena of the volcano during this time under the following heads:—

1. Morphology.
2. The lavas.
3. The fumaroles.
4. The mud flows.
5. The internal avalanches.

1. It would be interesting to be able to compare at a glance the external form of Vesuvius as it was at the time of the last repose-period—1872–1875—with its appearance at present; the difference would represent the constructional capacity of a single eruptive period and would be instructive in showing how rapidly the old crater basin of Monte Somma is being filled by the accumulations of lava and fragmentary ejecta. The slow flows of 1881–3, of 1885–6, 1891–4, 1895–9 and 1903–4 all formed lava-cupolas of considerable size which, with the sub-terminal streams on the westerly flank in 1905–6, form quite a regular distribution around the central cone. The great cupola of 1895–9 is especially important from a practical point of view, as showing the encroachment of the new Vesuvius on that spur of the ancient mountain—the Colle Canteroni—where stand the Royal Observatory and the Eremo Hotel. A glance at fig. 4 will show how little remains of that oasis in the desert of lava, and it would seem not improbable that one or two more eruptive periods—say sixty years of time—may suffice to cover the site; unless, indeed, the very presence of this great lava-mound with its roots shall prove to have so sealed the approaches in this direction that future flows here may be of rarer occurrence.

The rapid lateral outflows on the southeast flank during the last great eruption were not accumulative and did not materially alter the contour of the mountain although they were probably responsible for the great external collapse of the cone on that side; but the enormous quantity of fragmentary ejecta has altered the outline of the cone and greatly aided in the filling up of the Atrio del Cavallo, half obliterating the lava cupolas of 1891 and 1903 and rounding over the many little bosses—the so-called "Montagnelle"—resulting from these flows.

FIG. 2.

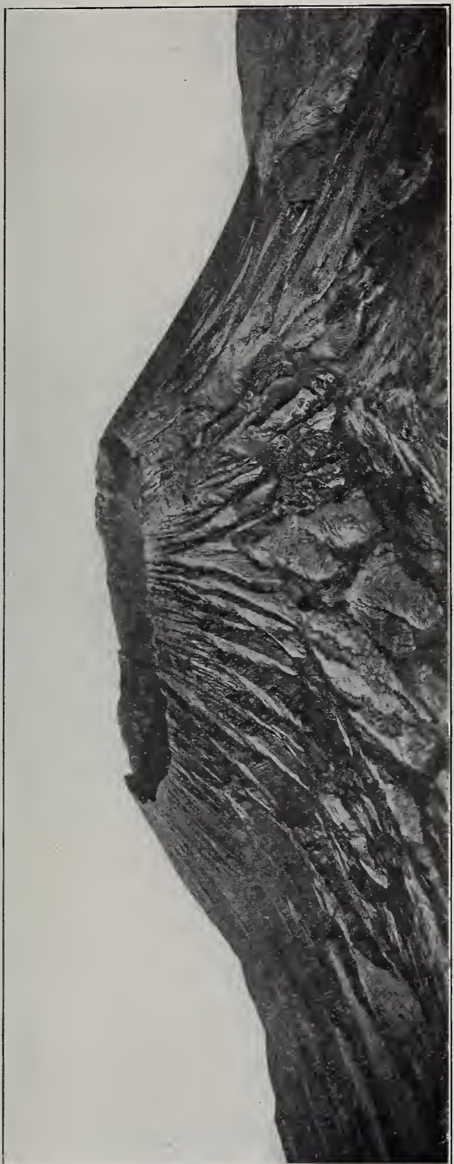

FIG. 2. Vesuvius—Panorama of the cone and crater from the northeast.

FIG. 3.

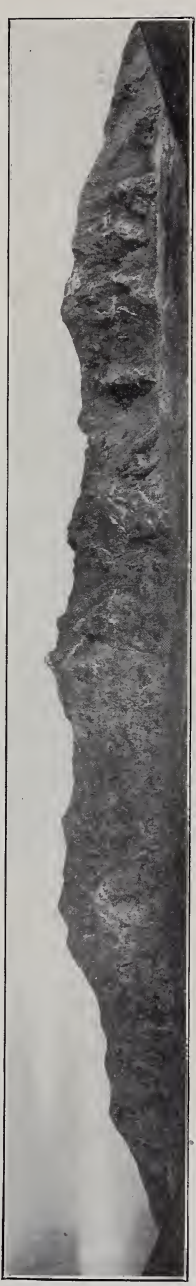

FIG. 3. Vesuvius—Panorama of Monte Somma and the Atrio del Cavallo.

The eruption left the cone obliquely truncated with the highest portion at the westerly rim of the crater, where the mountain is well braced with sills of lava. The lowest points were a "V"-shaped cleft on the rim to the north-northeast—the "échancrure" of Lacroix—and the easterly rim, where the cone is chiefly composed of friable material. Since the eruption the height on this side has been still further reduced by landslips, making the north and east the best general direction from which to obtain a view of the entire crater rim. Fig. 2 shows the appearance of the cone from this side, the photograph having been taken from the Cognoli di Ottaiano, due northeast of the crater, on Sept. 4, 1908. Since that time I have photographed the crater rim from the north in order to show by direct comparison the alterations since the eruption in the neighborhood of the "échancrure" (see fig. 5).

FIG. 4.

FIG. 4. Vesuvius—Colle Umberto, showing encroachment of its lavas on the Colle Canteroni.

The interior of the crater has also changed its form since the close of the eruption. At that time it might aptly have been likened to a funnel, the walls sloping inward at a moderate angle to a central well having almost perpendicular sides and of such a depth as to render the bottom invisible from any portion of the crater's edge. Subsequent downslips have altered the funnel shape to one more nearly resembling a cup the bottom of which is visible from many parts of the rim. The angle between this floor and the side walls is broken by many taluses corresponding with canals on the walls which give direction to the falling materials.

By far the best general view of the interior is obtained from the lowest portion of the northerly rim, and by frequently visiting this spot with the sun at its greatest north declination—i. e., in June and July—I have been able to compose the photograph reproduced in fig. 1 (Plate I). This shows the entire southern half of the great crater basin with the east, south and west walls, the talus at the bottom and a portion of the crater floor. The average height of the walls is approximately three hundred meters and the diameter across the top from left to right—east to west—about seven hundred and fifty meters. The north to south diameter is somewhat greater and the northwest to southeast a little less. The absence of any standard of comparison renders the picture disappointing to one who is familiar with the noble proportions of the crater, but a man on the opposite brink would

Fig. 5.


May, 1906

August, 1909

Fig. 5. Comparative views of the crater rim as seen from the north.

appear in the photograph as a mere speck, quite useless for the purpose of measurement.

2. The lavas of most interest at present are the sub-terminal flows of 1905–6 on the west-southwest flank. The accumulations of 1881–3 and 1885–6 have too far cooled down to be interesting, and the same may be said of those of 1891–4 and 1895–9 (Colle Margherita and Colle Umberto), although these still exhibit sensible surface temperatures with slight fumarolic action.* The most recent lavas—those of the rapid lateral outflows on the southeast flank during the last eruption—have cooled rapidly and show high temperatures only at or near their mouths of emission, where fumaroles bring hot vapors from the interior. In comparison with these the sub-terminal flows of 1905–6 on the west-northwest flank of the cone have shown a comparatively slow cooling. At a certain point where the path of ascent crosses one of the streams, Mercalli, in April, 1907 found that lead wires were fused while those of zinc were not, indicating a temperature between 325° and 412° C. In February, 1908 wires of tin were melted but not those of lead, indicating between 228° and 325°. On March 5, 1908 my electric pyrometer showed at the same point 244° and on September 3, 1908 it indicated 140°. On July 10, 1909 this had fallen to 65° C. On the main stream, which is somewhat farther to the south, the lava has greater depth and showed in July, 1909 a temperature of 175° C. This is at a point some hundred meters farther down the cone and is the site of the secondary fumaroles which have shown sublimations, as recorded in section 3.

There is also a sheet of lava on the north-northeast side of the cone under the "échancrure." The exact date of its emission is somewhat of a mystery, although it was probably during the early part of the last eruption. As a lava-stream it is of little importance, being of small volume and forming a self-arrested cascade of glacier-like appearance, but its outflow on this side of the cone was, in my opinion, one of the causes of the formation of the "échancrure." Photographs, far too numerous for reproduction, have been made of this and other characteristic details of the volcano in the belief that they will be useful for comparison in the future and in order that all features of the present repose-period may be properly recorded.

3. The fumaroles offer the most important field for investigation during the periods of repose, and it is regrettable that these have not been systematically observed. It is true that deposits and sublimates were collected after the erup-

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* Mercalli observed the lava of the Colle Umberto still incandescent in 1901, and I was able to char a stick in the crevices as late as 1905.

tion and these have been studied by Lacroix, Johnston-Lavis, Casoria and others, and I shall not take up this phase of the subject; but that to which I refer is continued observation at regular intervals of the temperature and chemical composition of the exhalations, both of which are so intimately related to the actual internal condition of the volcano. The little which I have been able to do in this direction is recorded in this section.

For measuring temperatures I find an electric pyrometer indispensable, not only on account of its wide range but also because the length of the fire-end permits of its introduction to the depth of a meter or more in the fumarole.

Fig. 6.

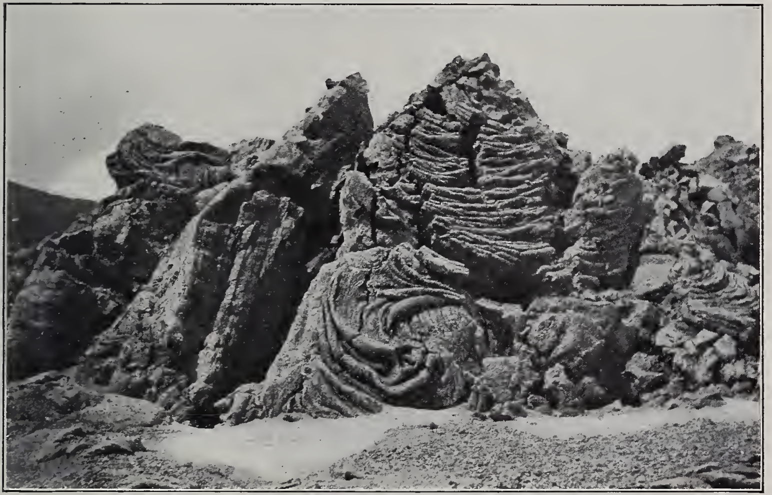

Fig. 6. Vesuvius—Corded lava of 1881–3.

The chemical investigation naturally divides itself into two branches, viz. field detection and laboratory analysis. For the former I use the following reagents, which are easily carried in a pocket case. Carbon dioxide is detected with limewater and sulphuretted hydrogen with lead acetate paper. For sulphur dioxide (SO_2) I have adopted a reagent proposed by the late Prof. Casoria* consisting of a precipitate formed by mixing together solutions of nitroprussiate of soda and chloride of zinc and adding ferrocyanide of potassium. The three salts have the following proportions:

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* "Una nuova carta rivelatrice dell' anidride solforosa," Eugenio Casoria, Portici, 1904.

Nitroprussiate soda	3 parts
Zinc chloride, fused	5 parts
Ferrocyanide potassium	3–4 parts

The precipitate is of a light yellow color, and is not affected by light. Spread on filter paper and moistened with dilute ammonia, it turns to a reddish purple when exposed to SO_2. It has the great advantage of not being affected by hydrochloric or hydrofluoric acids, both of which are so often present in fumarolic exhalations.

For the detection of hydrochloric acid a glass rod dipped in a solution of silver nitrate is exposed to the gases and immersed in dilute nitric acid, when, if HCl is present, the silver chloride formed will be precipitated. As an alternative, a strong solution of ammonia on a glass rod may be exposed to the gases with the formation of white vapors of ammonium chloride by hydrochloric acid, but the former test is more delicate and reliable, especially in a strong wind.

For laboratory analyses the gases are collected in expanded glass tubes, which are then sealed off with a benzine pressure lamp. It is generally necessary to aspirate the gases through the collecting tubes and for this a rotary tube-pump may be employed, but occasionally there is sufficient pressure to drive the gases through the tubes and through a water-valve at the farther end, provided the collecting tube is connected to a funnel placed over the fumarole and banked around with earth. Bunsen used tubes of tin for insertion in the fumaroles, but the temperature of some of the present Vesuvius vents precludes their employment. I have found no difficulty in using glass provided the tube is bent downward just above the fumarole, otherwise water condenses above and trickles down to the hot portion, causing the tube to crack.

In the general investigation of fumaroles it is important to note that those which develop on lava streams at a distance from their mouth of exit have no connection with the interior of the mountain, and cannot, therefore, serve as indicators of its condition. They are formed in connection with fractures in the lava stream and have an evanescent existence, which is doomed to extinction with the progressive cooling of the lava. These often act, for a time, as true fumaroles, bringing forth and depositing the volatilized products of the lava stream, but they soon degenerate into carriers of perfectly neutral hot air, with which, after rain, is mingled the vapor of water. They are not, therefore, true fumaroles of the volcano but fumaroles of the superficial lava stream, and are of the *secondary* type as contrasted with those which form in connection with fissures in the mountain, and which may be expected to rise in temperature with its increasing internal activity.

Secondary fumaroles formed in considerable numbers on the sub-terminal flows of 1905–6 on the west-northwest flank, the temperatures of which are recorded in the preceding section. For some time prior to the spring of 1909 chlorides and sulphates were deposited by some of these, but since then the emanations have been neutral, and the majority have been remarkable as mere purveyors of heated air. Ever since the eruption the large amount of water vapor given off by these fumaroles after rain has produced the appearance by day of an active lava stream.*

Fig. 7.

Fig. 7. Collecting gases from a fumarole at a temperature of 438° C.

Far different from these are the primary fumaroles on the northern flank of the cone, which are in communication with an important system of fissures formed in the mountain side during the eruption. They have been notable for their fairly high temperature ever since the eruption, and I have constantly insisted upon their importance. Early in 1908 I found 323° C. at one of these, and commenced a series of comparative observations which has several times been broken off in consequence of the destruction of the fumaroles by individuals who make a business of selling the minerals of the volcano.

The largest of the fumaroles has, until recently, remained intact. On March 5, 1908 the temperature here was 344° C.,

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* These vapors exhibit the well-known effect of increased visibility on the application of a lighted match.

and by September 3 this had increased to 435°. These fumaroles are acid and water vapor is present in small quantity, but the high temperature causes its absorption by the atmosphere without condensation. In March of 1909 I found 420°, but the pyrometer could not then be introduced at the same point owing to changes in the fumarole. On June 6 I found 428°, and on June 14, 438°, which is the highest I have observed. At this time the fumarole was spoiled for observation, as described above, and on July 9 the temperature was 430°, and on July 19 it was 416°—a progressive decrease due to the choking of the vent. This has begun to clear itself, however, and the temperature has since risen above 420°. I have commenced observations at another opening, which showed on July 9, 300° and on August 14, 308°.

The result of these observations shows that if the temperatures in this locality have not recently increased to any great extent, they are, at all events, not diminishing, and it is interesting and somewhat impressive to see, on this sleeping volcano, gases issuing quietly and almost invisibly at temperatures above the melting point of lead.

Before the destruction of this fumarole it had enlarged itself into the form of a grotto, at one end of which there could be seen an abundant incrustation of a white substance, evidently consisting of alkaline chlorides, but which were not of very recent formation. It is here that we most feel the lack of comparative chemical analyses made at regular intervals of time, but through the kind coöperation of Dr. Martin Henze, of the Zoological Station of Naples, I have, at last, been enabled to commence a series of investigations along this line. Gases and deposits were collected here on July 1, 1909, and the analyses, as made by Dr. Henze, are given herewith:

Water vapor (in small amount)	Detccted on the spot.
Hydrochloric acid	

Analysis of gas:

Oxygen	18·3	to	18·7	per cent.
Nitrogen	81·7	to	81·6	" "
	100·0		100·0	

Analysis of deposit:

White substance, soluble in water.

Bases: Na, K, Mg with traces of Al, Ca
Acids: HCl, H_2SO_4 a little, HFl traces

Proportion of the substances is in the order given.

As regards the gas we have atmospheric air which, as is usual in volcanic exhalations, is poor in oxygen. This is readily accounted for by its combination with other substances within the mountain—especially with H_2S in the production of SO_2. In the deposit the presence of magnesium in fair amount is interesting. Hydrofluoric acid is often found on Vesuvius.

It was decided to collect and analyze simultaneously with the above the products of a fumarolic area situated on the same side but below the cone itself, and less than two hundred meters from the escarpment of Monte Somma. Fumaroles appeared here through the sand immediately after the eruption, and, whether due simply to a continued existence of those on the underlying lavas of 1903–4, or to a revivifying of these by extension of the fissures on the cone to this point, the analysis of their products would form an interesting comparison with the above, because of their location at a greater distance from the central conduit and on a lower level.

Their temperature averages 98° C., and water vapor is abundant.

Analysis of gas:

H_2S	11·47	per cent.
CO_2	2·08	" "
O	11·47	" "
N	74·98	
	100·00	

Analysis of deposit:

Yellowish-white substance, soluble in water.

Bases: Al, Fe, Ca,
Acids: H_2SO_4, SO_2
Sulphur, from decomposition of H_2S.

At a nearby fumarole we found abundant deposits of realgar.

A veritable battery of fumaroles appeared inside the crater, just below the western rim, some time after the eruption. They are inaccessible, but their emanations consist largely of water vapor which is rendered more or less visible according to the condition of the atmosphere; and I must here insist upon the importance of taking this into consideration when judging of the activity of fumaroles. Reports are often made of a great increase or decrease in the emanations from day to day, or even during the same day; but it is evident that, excepting after rain, the output is fairly constant, and the visible changes are due to a varying capacity of the air for absorbing the vapor. A certain variation does, of course, occur, and it so happens that this is in correspondence with the humidity of the air, for it is when the atmospheric pressure is low that the vapors escape with greater facility, and this condition also brings moisture-laden air in which the fumarolic vapors cannot readily be absorbed. In cold, damp air the vapors condense and are rendered fully visible, while in a warm, dry atmosphere they are often absorbed without condensation, although their emission from the volcano may be no less abundant than in the former case. Some fumaroles with aqueous exhalations are so hot that the vapors are always expanded and absorbed by the atmosphere without condensation, and I have reproduced this phenomenon at the Solfatara of Pozzuoli by artificially heating the orifice of an aqueous fumarole, after which it was found impossible to effect the condensation of the vapor by the usual means.

Fig. 8.

Fig. 8. Vesuvius—A mud-flow in the Atrio.

I have recently found an important fumarole on the southeast flank of the cone and about one hundred meters below the crater. This has formed on one of the earlier lava flows of the last eruption, but it is evidently a true, primary fumarole although it is not acid at present. The temperature on July 10 was 235° C. Another which is very interesting is situated accessibly inside the crater on this side and, with a temperature of only 160° C., gives hydrochloric acid in considerable quantity. There is not a trace of SO_2.

4. The mud flows, as a destructive post-eruptive phenomenon, have formed a conspicuous feature of the repose-period. The eruption left the mountain covered with deep layers of sand in various degrees of fineness mingled with blocks and bowlders of every description, and, although the dry, hot avalanches during the paroxysm had carried much of this material off the cone, this only caused its removal farther down the mountain and thus nearer to inhabited parts. The rains which follow an eruption, and those of succeeding rainy seasons, seep through the sand until a certain consistency is reached, when the mass begins to flow as a mud stream carrying along the blocks and bowlders and acquiring considerable velocity. Following the ravines and gullies on the flanks of the mountain, the "mud-lava" invades the plains below, causing the destruction of houses, bridges and, not infrequently, of human life. The government has constructed, at great expense, a series of stone dams designed to impede the flows, and these have, on the whole, served the purpose fairly well. There now remains comparatively little of this movable material and the flows most often seen at present are of the self-arresting type, having the general shape of a glacier.

Fig. 9.

Fig. 9. Vesuvius—Water erosion on the mud-flows.

The movement of this material under the varying action of meteoric waters forms an interesting field for the study of denudation and drainage, the accumulations on gentle gradients showing beautiful erosion effects with arborescent trickle-patterns of great delicacy.*

5. The last eruption left great masses of material in unstable equilibrium around the inside of the crater's edge, and from time to time these were precipitated into the abyss, compressing the air by their fall, and were then ejected as immense dust-clouds which so perfectly resembled true explosions that reports of a new eruption were frequently seen in the newspapers. One of these great downfalls occurred while I was visiting the United States, and I took occasion to deny the report of an eruption and published an explanation of the phenomenon in the New York papers.

Fig. 10.

Fig. 10. Vesuvius—Effect of a large internal avalanche.

The downfall of these large masses soon raised the floor of the crater to a point some three hundred meters below the rim and subsequent avalanches have formed a series of talus cones around the circumference of this floor which are constantly growing and thus reducing the size of the flat, central area.

I use the word "avalanche" instead of "dry slip" or "landslide" as it conveys a more adequate idea of the grandeur of the phenomenon. Slips and slides are continually occurring, but the descent of a true avalanche in the present crater of Vesuvius

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* Compare Jaggar's "Experiments illustrating Erosion and Sedimentation." Bulletin of the Museum of Comparative Zoology at Harvard College, vol. xlix, 285, 1908.

forms one of the most impressive sights which can be imagined. Detachment sometimes takes place silently but more often with a sharp crack. The acceleration is almost equal to that of a freely falling body, as the crater walls are nearly perpendicular. Huge bowlders, rebounding from the sills of lava, are projected

Fig. 11.

Fig. 11. Vesuvius—Descent of an avalanche inside the crater.

horizontally and then descend in graceful curves, while the bulk of the avalanche, enveloped in whirling clouds, falls from precipice to precipice with the reverberating roar of thunder until it finally precipitates itself upon a talus at the bottom of the crater. Then ensues the development of a magnificent dust-cloud, flaring and torch-like at first, but it soon forms a compact cauliflower cloud of exquisite beauty, reminding one irresistibly of the "nuées ardentes".* The motion, both of translation and of development, is exceedingly rapid, and the cloud unfolds and advances with *sharply defined contours.* It should be noted that we have here no vapor of water, no high temperature and little, if any, electrical potential—nothing, that is to say, which could constitute anything like an "*emulsion*," and it would seem that all that is required for producing sharp outlines in a dust-cloud is sufficiently rapid projection against an air-cushion.

Fig. 12.

Fig. 12. Vesuvius—Development of an avalanche on reaching bottom of crater.

The smaller of these avalanches are interesting as showing more clearly the various phases of their development, the wind often blowing to one side the lighter dust, where it may

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*Lacroix, La Montagne Pelée, Paris, 1904.

FIG. 13.

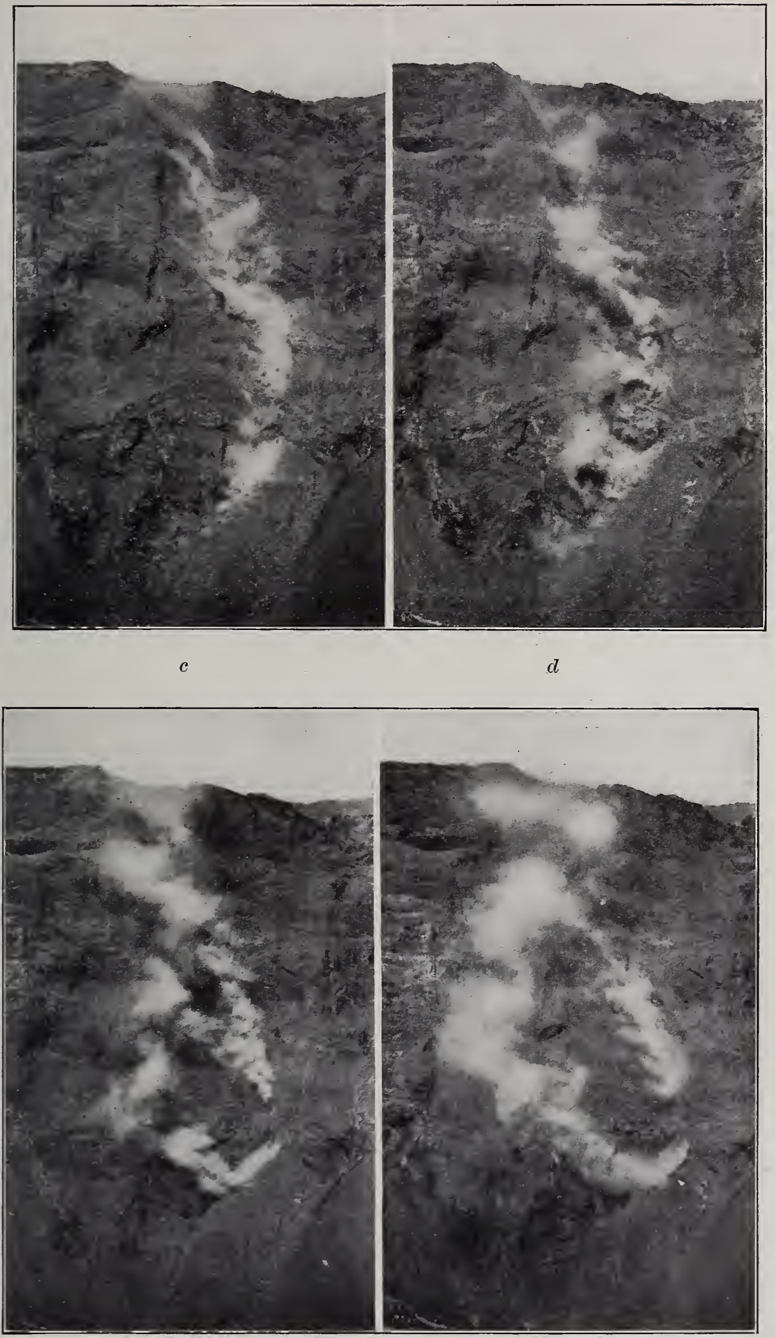

FIG. 13. Vesuvius—Four phases of a small internal avalanche.

be seen ascending near the still falling avalanche and thus forming two columns moving in opposite directions.

The avalanches have recently become more numerous. This is due, in my opinion, to increasing tension within the volcano, which causes the detachment of the materials by producing slight earth tremors. The northerly half of the crater rim is being by their means considerably reduced in height and altered in contour, as has already been shown in the section on morphology.

On this side of the cone I have recently observed, on a very small scale, a replica of the great *external* avalanches which formed so conspicuous a feature of the last eruption. The present ones are formed, curiously enough, in connection with those on the inside of the crater. So sharp is the rim on this side that when it crumbles a portion of the material, with possibly a bowlder or two, falls outward instead of inward and forms the nucleus of the external slide, which is limited by the small amount of readily movable substances upon the cone at present.

The sand-spiracles which were numerous at the close of the eruption, and which Lacroix and others have mentioned, are still to be seen occasionally. Fine sand is caught up in a vortex of wind forming a funnel like a miniature tornado, but generally very narrow throughout its length and perfectly straight. They have a rapid movement of rotation with a slow one of translation. I have not yet had the opportunity to photograph one of them.

As to the future, it goes without saying that the remainder of the repose-period, be it long or short, will be of even greater interest than that which is already past. Fumarolic activity should increase, earth tremors become stronger and more frequent, until finally—if the volcanic action follows normal lines—the magma shall have fused and forced its way upward in the central conduit to the crater, when a new period of external activity will be inaugurated. A systematic study of the signs of its coming would be of great value to the science of prediction.

In concluding, the writer desires to acknowledge his indebtedness to Dr. Martin Henze for the chemical analyses, to Prof. Mercalli for much valuble information and advice, to Herr Faerber, of Thos. Cook & Son, for materially facilitating his excursions on the mountain, and to Professor Jaggar for revision of the proofs of this manuscript.

Naples, Italy, Aug. 26, 1909.

Art. XL.—*The Great Nevada Meteor of 1894;* by Walter P. Jenney.

Mr. Henry C. Cutting, of San Lorenzo, California, relates that in the winter of 1893–4 he was living in Candelaria, Nevada, and witnessed the explosion of a great meteor, which passed directly over the town, about 10 p. m., Feb. 1st, 1894. The night was clear and tranquil, and the stars were shining brightly. The meteor came from the west, exploded with a blinding flash of light, followed after a short interval by the sound of the explosion, and finally passed out of sight to the east. Mr. Cutting does not recall that any one at Candelaria claimed to have seen the meteor before the flash—the first notice was the intensely bright light illuminating the whole sky.

Candelaria is situated on the eastern slope of a high hill which shut off any view of the meteor, coming as it did from the west, until it was nearly overhead. Mr. Cutting was in his house, when there came a terrific explosion so that the house shook with the air-wave; he thought that a powder magazine had exploded, and ran out of doors. He states that he saw a bright light overhead in the star-lit sky, and heard a roaring sound that reverberated like thunder, but more metallic, which lasted for two to four minutes, dying away in a vibration like the sound given off by a telegraph wire when struck. The blinding flash first seen was so intense that the whole landscape was lighted up, and the sagebrush on hills several miles distant could be distinctly seen; within houses with shutters tightly closed, the illumination was so strong that the most minute objects were visible.

Different observers compared notes respecting the interval that elapsed between the first flash and the sound of the explosion, and agreed that it was nearly thirty seconds. Assuming that the explosion took place vertically over the town, this would place the meteor at the moment of explosion at a height of six and one-half miles above the surface of the earth. When Mr. Cutting got out of the house, nearly all of the people in Candelaria were in the streets; there were 75 to 100 Chinamen, living in Chinatown, who were terribly frightened. After the meteor passed, the Chinamen set off firecrackers to scare the devil away. Some thought that the meteor fell a few miles to the east, and several parties went out to Summit Springs in search of it, but it was never found.

Observers at Silver Star* did not note the sound of the explosion, and the operator at Benton,* when called up by

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* Small towns near Candelaria.

telegraph, reported that he heard a faint noise; from all of which it appears that the explosion was nearly over Candelaria. The San Francisco Examiner telegraphed the operator at Candelaria for all the facts about the meteor, and an article on the subject was printed in the Examiner about February 5th to 10th, 1894.

Discussion by the Writer.

Other observers state that, immediately following the flash, the path of the meteor across the sky was a broad band of intense brilliant red, stretching from west to east; all the while the path was blazing with the combustion of material detached from the meteor in its flight. As the meteor passed on, the band of light gradually contracted in width, the sides coming together, and the light fading out until only a waning line of luminous smoke remained floating in the air for several minutes before it disappeared. Estimates made of the breadth of this band forming the track of the meteor vary widely; some saying it looked to be at least 25 feet wide; others, taking possibly into account the distance it must be away, thought the path blazed in the sky exceeded 100 feet in breadth, and might have been greater. Several tell that the meteor itself looked to be three to five times the diameter of the moon as she appears when rising.

It is probable that the explosion was caused by the formation of a thick crust resulting from the oxidation of the metal, which confined the gases generated in the nucleus—the force of the explosion dissipating in dust the outer shell. This is confirmed by the fact that no one saw the meteor break up; after the flash it continued its flight in a single path as long as it could be seen.

It should be noted that the meteor in its path, coming from over the Pacific Ocean, passed to the north of, and paralleled the Mount Diablo base line, passing north of San Francisco. This meteor is reported to have been seen, traveling across the sky far to the south, by people living at that time in Belmont, Nevada, so that it continued its flight at least fifty miles east of Candelaria, across the deserts of Nevada.

Peculiar interest attaches to the meteor of Candelaria since it seems probable that the great meteorite of Quinn Canyon, found in 1908, may be the part of it which reached the earth. This meteorite was described by the writer in the "Mining and Scientific Press" for Jan. 9, 1909, and the chief facts in regard to it are here repeated.

The meteorite was found in the latter part of August, 1908, by a prospector in the foothills of the Quinn Canyon range* in

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* Called in some maps the Grant Mountains.

Fig. 1.

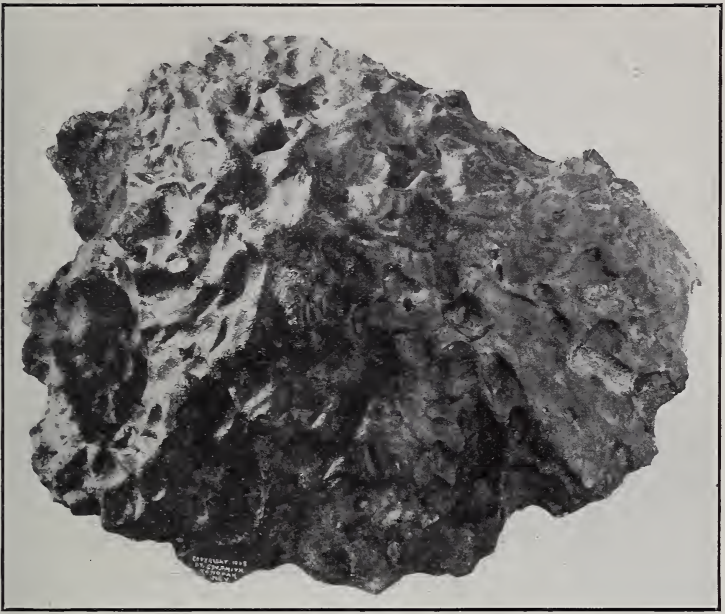

Fig. 1.—Quinn Canyon, Nevada, meteorite. Top view, length 44 inches, breadth 34 inches.

Fig. 2.

Fig. 2.—Side view; length, 44 inches, height 20 inches.

Nye county, Nevada; it was half buried in the soil. The place where the meteorite fell is almost uninhabited except for a few sheep herders; it is situated 90 miles due east of Tonopah, 18 miles north of the Mount Diablo base line, and 100 miles west of the Utah boundary.

The mass is roughly oval in shape, as shown in figures 1 and 2; the dimensions are 44×34 inches on the base with a height of 20 inches; the estimated weight is 4000 lbs. The upper surface is deeply channeled and pitted and covered with a thin smooth skin of magnetic oxide which has protected it from erosion; even the lower buried portion is but little rusted. The Widmanstätten figures appear on a smooth surface, when etched, as closely spaced, brilliant lines on a black ground; an octahedral structure seems to be shown on portions of the surface. A partial analysis has shown the presence of 5 to 10 per cent of nickel alloyed with the metallic iron.

The mass has been transported with much labor to Tonopah, where it is now preserved.* It has been carefully handled, and except for a few ounces cut off with a cold chisel by the prospector who found it, it is now practically as it fell. A careful inspection of the meteorite before it was removed from the spot where it was found, led to the conclusion that its fall was comparatively recent, probably within the last twenty years. It is with much plausibility connected with the Nevada meteor, described above, of February 1, 1894, since it was found just about where the nucleus of the meteor might have been expected to strike the earth.

Tonopah, Nevada.

* This meteorite has recently been acquired by the Field Museum of Natural History at Chicago.

Art. XLI.—*The Phenomena of the Electrolytic Decomposition of Hydrochloric Acid;* by F. A. Gooch and F. L. Gates.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cciv.]

According to the prevailing theory of electrolysis, all the ions of a solution, of whatever nature, are acted upon by the electric forces and all carry the current by moving through the solution. If more than one kind of ion is present that kind which has the lowest deposition voltage is first deposited at the electrode.

In the decomposition of hydrochloric acid the hydrogen ions derived from the acid travel to the cathode and are there converted into neutral hydrogen. The chlorine ions move to the anode, and if the solution is fairly concentrated, are there discharged and converted to neutral chlorine. Under such conditions, the hydroxyl ions of the solvent, water, having a higher decomposition value than the chlorine ions, take part in the transfer only to an insignificant extent. As the concentration falls to the point where the diffusion of the acid in solution is insufficient to replace the chlorine ions which are removed from the layer of liquid in contact with the anode, the hydroxyl ions of water may take part in the transmission of the current from the solution to the electrode, and the polarization rises until in extremely dilute solution it approximates the decomposition value of water. From strong solutions of hydrochloric acid the gases evolved are hydrogen at the cathode and chlorine at the anode, while as the concentration decreases oxygen from hydroxyl is evolved in place of chlorine. LeBlanc has shown experimentally the following decomposition values for varying concentrations of hydrochloric acid:

	Decomposition Value
2 Normal HCl	1·26 volts
$\frac{1}{2}$ " "	1·34 "
$\frac{1}{6}$ " "	1·41 "
$\frac{1}{16}$ " "	1·62 "
$\frac{1}{32}$ " "	1·69 "

According to this theory the transmission of the current from the solution to the electrode is effected at the highest dilution primarily by the ions of water, while in the interior of the solution the current is presumably carried almost entirely by the ions of the acid.

A recent series of articles by Doumer* contains the account of experiments in the electrolysis of hydrochloric acid

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* Compt. Rend., cxlvi, 687, 897.

and certain derived inferences as to the part played by water in carrying the current of electricity and as to the speed of transportation of the chlorine and hydrogen ions. In the experiments first recorded,* an electrode of platinum wire 0·5$^{\mathrm{mm}}$ in diameter and 6$^{\mathrm{cm}}$ in length was used, and in these experiments it was found that the volumes of oxygen delivered free at the anode, by currents ranging from 0·120$^{\mathrm{amp}}$ to 0·134$^{\mathrm{amp}}$, continued through intervals of about an hour, bore to the volumes of hydrogen simultaneously set free at the cathode a relation changing with the concentration of the solution. Taking the volume of hydrogen evolved as unity, the ratios of the volumes of oxygen and hydrogen, expressed fractionally for varying concentrations, are as follows:

Concentration per thousand:	14·5	8·7	5·8	2·9	1·45 (?)	0·72
Ratio of oxygen to hydrogen:	0·034	0·068	0·082	0·120	0·166	0·212

Similar results were obtained in another experiment in which a silver anode (of unrecorded dimensions) was employed to fix the chlorine; but the evolution of oxygen was found to be relatively greater, the ratio for a concentration of 0·72 parts of hydrochloric acid to 1000 parts of solution being 0·253 as compared with 0·212 obtained under similar conditions with the platinum anode. From the fact that the evolution of oxygen did not cease, but was rather actually increased under such conditions, Doumer drew the conclusion that the liberation of oxygen in the electrolysis of hydrochloric acid cannot be attributed to the secondary action of chlorine on the water of the solution, and that there is direct electrolytic decomposition of water as well as of acid.

In a subsequent article† the account is given of a similar experiment, with the silver anode, in which readings of the gas delivered were taken through twenty consecutive periods of five minutes each. It is stated that when a silver anode is employed for the electrolysis of hydrochloric acid, brown silver oxide is formed until the deposit of oxide and chloride upon the anode reaches a thickness which it does not seem able to exceed, and that thereafter the liberation of oxygen becomes constant, while the chlorine produced in the electrolysis remains fixed on the anode as silver chloride. The liquid contains no trace of free chlorine or of oxychlorides when weak currents are employed. During the first twenty minutes of preliminary electrolysis, in the experiment recorded, no note was taken of the volumes of gas liberated. For the first

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* Compt. Rend., cxlvi, 329–331.

† Compt. Rend., cxlvi, 687–690.

five periods following the preliminary interval, the volumetric ratios of oxygen to hydrogen were 0·247, 0·272, 0·285, 0·319. Thereafter, in the remaining fifteen periods, the oxygen-hydrogen ratios were nearly constant at an average of 0·332. Practically the same average ratio (0·331) is recorded for observations taken under varying conditions of current and concentrations of hydrochloric acid in water; viz., a current of $0·006^{amp}$ and $0·023^{amp}$ in a solution of 1·25 to 1000; $0·021^{amp}$ and $0·250^{amp}$ in a solution of 5·3 to 1000; $0·020^{amp}$ and $0·100^{amp}$ in a solution of 10·7 to 1000; and $0·053^{amp}$ in a solution of 55·8 to 1000. The conclusion was therefore drawn that the ratio of the volumes of oxygen liberated at the anode to the volume of hydrogen received at the cathode in the electrolysis of hydrochloric acid is constant and independent of the intensity of the current and concentration of the solution; and, inasmuch as a subsequent experiment with a mercury cathode established a closely concordant ratio, it was further concluded that the ratio is, perhaps, also independent of the nature of the anode.

The ratio of the volume of hydrogen equivalent to the liberated oxygen to the total volume of hydrogen taken as unity, Doumer calls the "factor of ionization of water," and this factor, 0·662 or about $\frac{2}{3}$, expresses the view that of the hydrogen received at the cathode about $\frac{2}{3}$ is derived from water and $\frac{1}{3}$ from hydrochloric acid; and that for every molecule of hydrochloric acid electrolyzed one molecule of water must also be electrolyzed, if water is ionized to $2\overset{+}{H}$ and $\overline{O}$,—or two molecules, if water is ionized to $\overset{+}{H}$ or $\overline{OH}$.

A still later communication* deals with velocity of movement of the chlorine and hydrogen ions. Upon the hypothesis that two-thirds of the current is carried by the ions derived from water and one-third by the ions derived from hydrochloric acid, Doumer calculates that the loss of acid should be the same at both electrodes. This was found to be the case in each of three experiments made with a silver anode in weak solution and with a feeble current. Doumer, therefore, summarizes the results in the statement that (1) the ionization of water interferes in active fashion in the electrolysis of solutions of hydrochloric acid, and that (2) the speed of transfer of the ions H and Cl is practically the same.

The earlier and very elaborate transfer experiments by Noyes and Sammet† lead to precisely the same conclusion as to the ionic velocities, provided it be assumed that two-thirds of the current is carried through the solution by ions derived from water. In these experiments, in which standardized hydrochloric acid was electrolyzed between a platinum

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*Compt. Rend., cxlvi, 894–896.

†Jour. Amer. Chem. Soc., xxiv, 949.

cathode and an anode consisting of a silver disc about $3{\cdot}5^{cm}$ in diameter, the current density not exceeding 4·5 milliamperes to the square centimeter, chlorine was not evolved; but some oxygen was liberated, and in every case silver chloride formed a cloud about the anode. The transfer number calculated from the total amount of silver deposited in the voltameter and the change in the strength of the acid at the cathode agreed very closely with the number based upon a comparison of voltameter indication with the change in the chlorine content of the anode material, this chlorine content having been found by determining the fixed silver chloride together with that precipitable by silver nitrate from the anode liquid. The titration of the anode liquid for acidity gave, however, utterly discordant results, owing probably, it is said, to the liberation of some oxygen at the electrode and the production of a corresponding quantity of acid. The transfer number calculated for chlorine, upon the hypothesis that all the current was carried by the ions of hydrochloric acid, varied somewhat with the dilution and temperature, but, at 29° for N/20 and N/60 solutions, was on the average 166·6; but if it were assumed, with Doumer, that one-third of the current passing is applied to the electrolysis of hydrochloric acid, and one-third of the entire indication of the voltameter were taken as the measure of amount of current used solely in the electrolysis of hydrochloric acid, the transfer number for chlorine would become 499·8 and would indicate, as did Doumer's direct tests of acidity at the anode and cathode, that the hydrogen and chlorine ions have the same velocity.

In the work of Noyes and Sammet conditions were adjusted to restrict as far as possible the evolution of oxygen and regeneration of acid. In that of Doumer conditions were arranged to secure the maximum evolution of oxygen; and Doumer's inference that one-third of the current is always utilized in electrolyzing hydrochloric acid rests fundamentally upon the generalization that the proportion of anode oxygen to cathode hydrogen is constant and independent of the strength of current and of the concentration of the solution.

In the work to be described we have further studied the electrolysis of hydrochloric acid under various conditions. In the experiments recorded in Table I, A, the apparatus used, and shown in figure 1, was a Hoffman apparatus provided with a Hempel leveler, so that the gas measurements might be made at the atmospheric pressure, and the electrodes were introduced through rubber stoppers. In other experiments, detailed in Table I, B, the apparatus was provided with an anode which consisted either of a silver filtering crucible fitted with an asbestos mat or of precipitated silver placed upon the mat of a porcelain filtering crucible, as shown in figure 2. This apparatus was so adjusted that standardized acid might be run in from the leveler to replace the anode liquid slowly

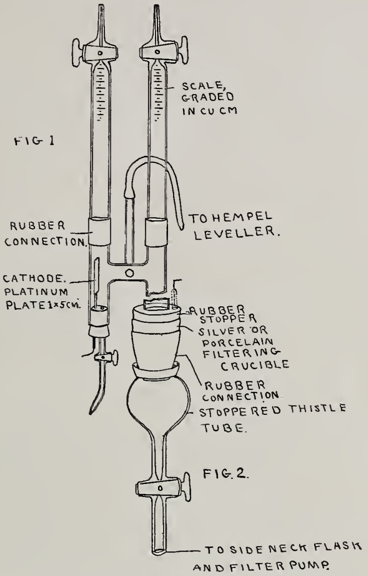
FIG 1

FIG. 2.

filtered away to keep the composition of the electrolyte constant and to collect detached and colloidal silver chloride.

TABLE I.—*Anodes of Silver.*

Time min.	Current amp.	Potential volt	Concentration: parts in 1000	Hydrogen cm^3	Oxygen cm^3	Ratio of Oxygen to Hydrogen	Approximate Area of Silver Anode cm^2
				A			
31	0·085	88–89	0·73	23·94	3·44	0·143	1·0
31	0·080	28–32	0·73	22·40	2·60	0·116	21·4‡
30	0·080	83–90	0·73	22·44	0·32	0·014	14·0§
				B			
30	0·050	90	0·36*	14·9	0·9	0·060	? ‖
30	0·050 0·045	95	0·36†	12·9	0·03	0·002	20¶
30	0·070	60–65	0·73*	20·1	3·75	0·186‡	20¶
30	0·070	62–65	0·73*	20·2	none	0·000§	20¶

* Nearly N/50. † Nearly N/100. ‡ Anode previously used. § Surface of anode fresh. ‖ About 3 grs. of precipitated silver in porcelain. ¶ Silver crucible.

From the results given it is obvious that, under the conditions, oxygen was liberated only when the silver surface open to attack was small and in no case attained the proportion noted by Doumer. Though Doumer states, in regard to his earlier experiments at least, that no chlorine or oxygen-acid of chlorine was found in the anode liquid, according to our experience when oxygen was set free it was always accompanied by at least a recognizable amount of chlorine. Silver oxide in mixture with silver chloride was observed upon the anode in every experiment, and the formation of the oxide began as soon as the electrolysis was started. It seems plain that so long as the anode exposes a large silver surface, open to easy attack, both oxygen and chlorine attack it. Silver chloride once attached may remain fixed upon the anode, but silver oxide is subject to the action of the hydrochloric acid as well as to that of liberated chlorine, ionized or molecular. Only when the attackable surface becomes sufficiently limited does the evolution of oxygen begin, and it was repeatedly noted that an established evolution of oxygen could be easily interrupted by disturbing the protecting film upon the anode.

The formation of the easily diffusible colloidal silver chloride which occurs when the free surface of the silver anode is restricted and the potential across the electrodes rather high, can hardly be due to the simple action of chlorine upon silver since it does not take place when a silver anode surface is freely exposed. Apparently the production of silver oxide precedes the formation of the colloidal chloride. According to our experience, when freshly precipitated silver chloride is submitted to the action of dilute hydrochloric acid it gradually becomes more crystalline, and not colloidal, while dilute hydrochloric acid acts upon silver oxide to form finely divided silver chloride, and the formation of cloudy colloidal silver chloride takes place characteristically when silver oxide held in platinum gauze is dipped into chlorine water, soluble silver hypochlorite being, no doubt, formed simultaneously. So it would seem that the condition under which colloidal silver chloride is most likely to form in the electrolysis of hydrochloric acid exists when silver oxide formed upon the anode is liable to the attack of chlorine, some silver chloride being formed in the direct action of chlorine upon silver oxide, and some by the action of the hydrochloric acid of the solution upon soluble silver hypochlorite. This, it seems to us, is probably the action which in every case gave rise to a cloud of colloidal silver chloride about the anode in the transference work of Noyes and Sammet* with solutions of chlorides.

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* Loc. cit.

In the following experiments the silver anode was protected by a layer of silver chloride to restrict as far as possible the surface open to the attack of oxygen. The anode of silver wire, 2·27^{mm} in diameter and 4^{cm} long, was first dipped in melted silver chloride and then made the rapidly rotating anode in a preliminary electrolysis of fairly strong hydrochloric acid until chlorine was freely evolved. In this way the anode was made inert excepting at imperfectly covered points, with the practical effect of very much limiting the active area and, incidentally, of increasing the current density for given strengths of current. Not every anode thus prepared was perfect enough to be used through an experiment without formation of colloidal silver chloride, but some serviceable anodes were thus obtained, and with them the experiments recorded were made. For these experiments the form of the apparatus was changed to permit movement of the electrodes and a corresponding adjustment of potential across the electrodes for different concentrations. The apparatus is shown in figure 3. In Table II are given the results in summary.

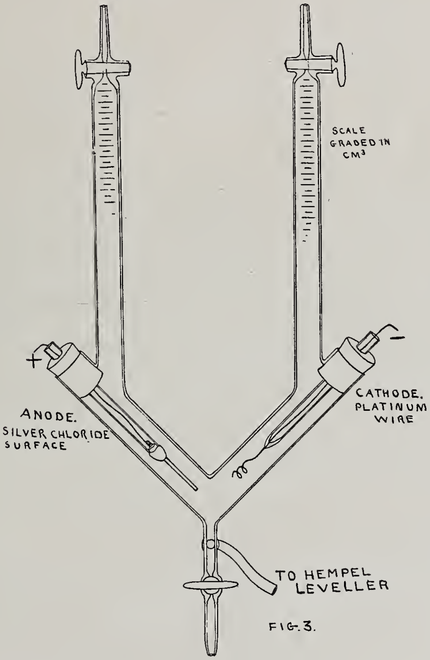

FIG. 3.

TABLE II.—*Anodes of Silver protected by Silver Chloride.*

Time min.	Current amp.	Potential volt	Concentration: parts in 1000	Hydrogen cm³	Oxygen cm³	Ratio of Oxygen to Hydrogen
30	·05	11·3	4·3	14·9	3·6	·242
30	·05	12·5	0·86	13·6	4·0	·294
30	·05	12·5	0·43	14·8	5·0	·338
30	·10	21·0	0·86	26·1	6·4	·245
30	·10	21·6	0·86	25·5	6·7	·263
30	·10	21·3	0 86	24·6	8·0	·325
30	·10	20·3	0·43	26·3	8·3	·316
30	·10	21·6	0·43	25 0	8·3	·332
30	·15	26·6	4·3	39·7	10·5	·264
30	·15	28·5	0·86	37·5	11·8	·315
30	·15	29·5	0·43	37·9	12·5	·330

In these experiments the ratio of oxygen to hydrogen, though, within the defined limits, not materially or regularly affected by variations in the strength of current, the potential across the electrodes, or the current density, is seen to increase markedly as the concentration of the solution decreases. Only at the lowest concentration of 0·43 parts in 1000, and with an anode of very limited active area, was the average value as high as that obtained by Doumer. Our results, therefore, are at variance in this respect with those of Doumer. We find that the ratio of the volumes of oxygen and hydrogen evolved in the electrolysis of hydrochloric acid depends directly upon the concentration of the solution; and further that, at a concentration of 0·43 parts in a thousand, Doumer's ratio is obtained only when the anode is largely protected from the action of chlorine as well as oxygen.

This being the case, it is interesting to discover how these results obtained with the protected silver anode may compare with those obtainable by means of platinum anodes for similar concentrations of the solution. In the following table are given the details of experiments made with a spiral of platinum wire ($0·8^{mm} \times 5^{cm}$) used as the anode and solutions of similar concentration.

It is apparent that for the lower concentrations, 0·86 parts and 0·43 parts in a thousand, the ratios of the volumes of oxygen or hydrogen are, in the average, but slightly lower than those obtained when the protected silver anode is employed. For the higher concentration, 4·3 parts in a thousand, the ratio proves to be much lower than that obtained with the silver anode, possibly because, at the higher concentration of the acid, the effect of the very much higher

Table III.—*Platinum Anode.*

Time min.	Current amp.	$N.D._{100}$ amp.	Potential volt	Concentration: parts in 1000	Hydrogen cm^3	Oxygen cm^3	Ratio of Oxygen to Hydrogen	Mean for each concentration
				Anode area $=1·25^{cm^2}$				
30	0·10	8·0	4·0	43·0	27·6	2·3	·083	·083
30	0·05	4·0	12·0	4·3	14·1	2·3	1·63	----
30	0·10	8·0	20·5	----	26·2	3·7	1·41	----
30	0·15	12·0	28·2	----	38·8	6·2	1·59	·154
30	0·05	4·0	13·2	0·86	15·2	4·4	·289	----
30	0·10	8·0	21·2	----	28·6	7·1	·242	----
30	0·15	12·0	30·0	----	39·4	10·6	·268	·266
30	0·05	4·0	14·0	0·43	14·4	4·8	·333	----
30	0·10	8·0	20·8	----	25·6	7·9	·308	----
30	0·15	12·0	28·3	----	37·	11·9	·321	·320

but undeterminable current density upon the silver anode may be important. The ratios obtained with the platinum anode are never higher than those got by the use of the silver anode, and this fact leads reasonably to the use of the platinum anode in solutions of still lower concentration. For, though in the experiments described the protected silver anodes were practically unattackable at the current densities required for the electrolysis of solutions of the concentration employed, when the attempt was made to extend the range of experimentation to the electrolysis of solutions of hydrochloric acid of much lower concentration, it was found that the chloride coating of the anode became disintegrated. In the study of solutions of extreme dilution, therefore, it became necessary to revert to the use of platinum electrodes, and this we have found to be quite feasible. Table IV gives the details of an experiment upon a solution of the concentration of 0·043 parts in 1000, with a spiral anode and cathode of platinum wire $0·8^{mm}$ in diameter and 5^{cm} long, and in the apparatus of fig. 3. The gas evolved at the anode during the first thirty minutes (A) was measured at intervals of five minutes and recorded as oxygen, without correction for the possible presence of intermixed chlorine. The experiment was continued similarly for a period of forty-five minutes (B), at the end of which the measured anode gas was withdrawn, washed with sodium hydroxide and measured in a Hempel burette with a consequent diminution in volume amounting to $0·5^{cm^3}$ on the $25·4^{cm^3}$ originally found. At the end of another period (C) of forty-five minutes the anode gas was again withdrawn, and proved to be free from chlorine by testing with potassium iodide. So it is probable that the slight diminution found in washing with sodium hydroxide the anode gas of the first two runs was due to solubility of oxygen rather than to the presence of chlorine.

The details of five-minute readings and the finals are given in the table.

TABLE IV.—*Anode of Platinum: Area 1·25*$^{cm^2}$.

Volume of Solution=330$^{cm^3}$

Time min.	Current amp.	N.B.$_{100}$ amp.	Potential volt	Concentration: parts in 1000	Hydrogen cm^3	Oxygen cm^3	Ratio of Oxygen to Hydrogen
				A			
Start	·07	5·6	87·	0·043	----	----	----
5	·095	7·6	87·5	----	3·7	1·7	----
10	·105	8·4	87	----	4·0	1·7	----
15	·105	8·4	87	----	3·9	1·8	----
20	·105	8·4	87	----	4·1	1·7	----
25	·100	8·0	86·5	----	4·0	1·7	----
30	·100	8·0	86·5	----	4·1	1·7	----
					23·8	10·3*	·433
				B			
5	·100	8·0	85	----	3·9	1·7	----
10	·100	8·0	85	----	4·0	1·6	----
15	·100	8·0	84	----	3·7	1·6	----
20	·095	7·6	86	----	4·1	1·8	----
25	·105	8·4	87	----	4·0	1·7	----
30	·100	8·0	86	----	3·7	1·7	----
35	·095	7·6	86	----	4·0	1·8	----
40	·100	8·0	85	----	3·5	1·6	----
45	·100	8·0	85	----	3·7	1·6	----
					34·6	15·1†	·436
				C			
5	·09	7·2	90	----	3·4	1·6	----
10	·09	7·2	87	----	3·6	1·6	----
15	·09	7·2	90	----	3·7	1·7	----
20	·09	7·2	90	----	3·6	1·7	----
25	·09	7·2	89	----	3·7	1·6	----
30	·09	7·2	87·5	----	3·6	1·6	----
35	·09	7·2	87	----	3·5	1·4	----
40	·085	6·8	87	----	3·7	1·8	----
45	·100	8·0	87	----	4·0	1·6	----
					32·8	14·6‡	·445

* Uncorrected for chlorine.

† Uncorrected for chlorine. After washing with NaOH the 25·4$^{cm^3}$ of A and B was reduced to 24·9^{cm}.

‡ Proved free from chlorine by KI.

In this experiment the ratio of oxygen to hydrogen was fairly constant throughout the entire period of electrolysis and higher by about thirty per cent than Doumer's ratio and the maximum obtained at the lowest previous concentration of the solution. It is interesting to note, moreover, that the 91·2$^{cm^3}$ of hydrogen evolved in the two-hour runs is the equivalent of about 0·276 grm. of hydrochloric acid, or of nearly twenty times the 0·014 grm. of acid originally contained in the 330$^{cm^3}$ of solution. If all the hydrogen was derived from the primary electrolysis of hydrochloric acid, an amount of the latter equal to nearly twenty times that originally present must have been electrolyzed and regenerated in the course of the experiment.

The details of similar experiments with platinum electrodes of different areas and in solutions of still lower concentrations are given in summary in the following table. In A are given the results obtained at various concentrations with an anode of small area, while in B are given the results obtained with an anode surface eighty times as large.

TABLE V.—*Anode of Platinum.*

Time min.	Current amp.	ND_{100} amp.	Potential volt	Concentration: parts in 1000	Hydrogen cm^3	Oxygen cm^3	Ratio of Oxygen to Hydrogen	Mean for each concentration
				A				
				Anode Area=1·25^{cm3}				
30	0·05	4·0	23·4	0·172	14·6	5·7	·390	----
30	0·10	8·0	85·7	----	24·2	9·9	·409	·399
30	0·05	4·0	97·2	0·086	11·0	5·0	·454	----
30	0·10	8·0	87·3	----	24·7	11·1	·468	·461
30	0·05	4·0	95·2	0·043	12·2	5·4	·442	·442
30	0·039	3·12	98·7	0·0086	8·6	4·1	·477	·477
				B				
				Anode Area=100^{cm2}				
30	0·10	0·10	86·7	0·172	24·0	9·1	·379	----
30	0·05	0·05	95·8	0·086	12·8	5·2	·406	----
30	0·05	0·05	92·8	0·093	11·6	4·7	·405	----
30	0·031	0·031	95·8	0·0086	8·8	3·7	·420	----

The experiments of each series confirm in a general way the former evidence to the effect that the proportion of oxygen liberated increases as the concentration of the solution decreases. The highest ratio of oxygen to hydrogen, found at the lowest concentration, 0·0086 parts in one thousand, and at the high current intensity, is within five per cent of what it would be were water the primary and sole electrolyte. A comparison of the two series shows that a very large increase in area of the anode is attended with some decrease in the proportion of oxygen set free; or, in general terms, an eighty-fold increase in the current density involves, in the average, a ten per cent increase in the oxygen ratio.

It will be seen that the experimental results of which an account has been given contravene Doumer's claim that the ratio of the volumes of hydrogen and oxygen evolved in the electrolysis of hydrochloric acid is constant and independent of the strength of the current and concentration of the solution. They afford, therefore, no basis for Doumer's calculation of equal velocities for the hydrogen and chlorine ions. Nor does Doumer's discovery of equal acidity at the electrodes establish such a relation of velocities; for, if it be assumed that the current is carried by the ions of hydrochloric acid we have 166·6, according to Noyes and Sammet,* for the transfer number of chlorine at a concentration at which the oxygen-hydrogen ratio approximates Doumer's figure, 0·332; and if it be further assumed that the oxygen evolved is set free by the action of transferred chlorine ions with simultaneous regeneration of hydrochloric acid, the condition which produces the evolution of oxygen corresponding to the oxygen-hydrogen ratio 0·332 must result in the production of equal acidity of the electrode liquids.

The observed phenomena afford, therefore, no criterion for deciding how much of the oxygen liberated in the electrolysis of hydrochloric acid under any given conditions is transferred through the liquid and how much is evolved by the action of transferred chlorine at the anode.

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* Loc. cit.

ART. XLII.—*Eocene Fossils from Green River, Wyoming;* by T. D. A. COCKERELL.

PLANTS.

FIRMIANITES gen. nov. (Buettneriaceæ.)

Rather large globose capsules, with apparently five carpels (three visible in the type, one side of which is exposed), the surface smooth.

Firmianites aterrimus sp. nov.

Capsule about $13\frac{1}{2}^{\text{mm}}$, long and broad, as preserved shining coal-black, the longitudinal sutures evident, slightly raised above the general surface.

Hab.—On red shale, in the insect-bearing beds, Green River, Wyoming. (Eocene.) These fruits closely resemble those of the living genus *Firmiana*, found in China and Japan, and extending in a single species to Africa. It is not impossible, perhaps, that they actually belong to that genus, but it is no doubt much more likely that they represent some allied type no longer living. Among the described fossil fruits, there is a distinct resemblance to *Apeibopsis*, which, however, has many more divisions.

An apparently related fruit is *Palmocarpon corrugatum* Lesquereux, Tertiary Flora, pl. xi, f. 11. As this has more than three carpels, it cannot be a palm; it must be known as *Carpolithes corrugatus.* It is from the Basal Eocene at Golden, Colorado.

COLEOPTERA: OTIORHYNCHIDÆ.

Syntomostylus (?) fortis n. sp.

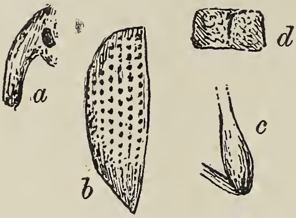
Length (excluding rostrum) $10\frac{1}{2}^{\text{mm}}$; rostrum about $2\frac{1}{4}^{\text{mm}}$, robust; elytra $7\frac{3}{5}^{\text{mm}}$ long and 3 broad, with seven rows of very large and strong punctures, becoming small and feeble apically; about the middle of the elytra there are about two punctures to one mm.; eyes elongate; thorax much broader than long, rugose; anterior femora moderately swollen; hind femora slender basally, but apically much swollen, their apices nearly level with the tip of the abdomen; elytra pointed apically. The following measurements are in μ:

Greatest width of hind femora (near apex)	900·
Breadth of rostrum about	850·
Length of eye about	850·
Breadth of eye about	375·

Hab.—On red shale of Eocene age, Green River, Wyoming; collector unknown. This is much the largest of the Green

River weevils. It may or may not be congeneric with Scudder's *Syntomostylus rudis*, which is known from elytra only, found in Eocene rocks in western Colorado. *S. rudis* is a smaller species (length of elytra 5^{mm}), but in the character of the ridges and punctures, and especially in the acute apex, it agrees well with *S. fortis*. (It may be well to note that in Scudder's Tertiary Rhynchophorous Coleoptera, p. 50, a wrong reference to the figure of *S. rudis* is given; it should be fig. 10, not fig. 2.)

Fig. 1.



Syntomostylus fortis.
a. snout, *b.* elytron, *c.* hind femur and base of tibia, *d.* thorax.

Fig. 2.

Firmianites aterrimus.

Art. XLIII.—*Note on the Occurrence of an Interesting Pegmatite in the Granite of Quincy, Mass.*; by C. H. Warren.

Recent operations in the quarry of Follen Bros. on North Common Hill, Quincy, Mass., have exposed a mass of pegmatite of such unusual mineralogic interest that it seems desirable to publish a brief preliminary notice regarding its main features. The occurrence was first brought to the writer's attention by Mr. F. Wesley Fuller, of West Quincy, and subsequently through the courtesy of the owners of the quarry, Professor Charles Palache of Cambridge and the writer were enabled to make a study of the mass in place and to secure abundant material, which is now being studied in detail with the intention of publishing later more fully regarding it. The pegmatite was encountered near the southern side of the quarry about 50 ft. below the surface. It appears to be a huge schlieren of rudely lenticular shape having a maximum thickness of 6 or 7 ft. and a depth and length of about 20 ft. Its position in the granite is nearly vertical. Another much smaller mass is said to have been taken out nearby.

The contact between the normal granite and the pegmatite is marked by a narrow band (2″ to 8″) of granite, finer in texture, poorer in quartz and much richer in hornblende than the normal granite. It shows a well-marked flow-structure. The pegmatite as a whole, although quite variable in texture and composition, still preserves a certain symmetry of structure. Just within the dark band is a broad zone of rather fine-grained pegmatite consisting essentially of orthoclase, quartz, riebeckite, and ægirite. Of these the riebeckite is the most conspicuous mineral, forming long black crystals suggesting somewhat the tourmaline of other pegmatites. In this zone is a considerable amount of graphic-granite, particularly as a narrow band about the margin. The zone also contains considerable amounts of fine-grained material, mineralogically similar to the coarser, scattered irregularly through it. In some parts the pegmatite passes centrally into masses of quartz a foot or more in thickness. The quartz along its margins contains large prisms of riebeckite covered with a mantle of ægirite and also long acicular crystals of ægirite generally arranged in radial clusters. Both of these minerals grow into the quartz from the pegmatite without. Toward what may be considered the main central portion of the mass the pegmatitic material gives way to a fine-grained rock, consisting essentially of orthoclase (and albite), ægirite and quartz. Still nearer the center the ægirite-feldspar rock becomes much coarser in grain, at the same time full of cavities and so loosely coherent that it may be easily broken up. The minerals, particularly the ægirite, project out into the open spaces. Quartz is now less abundant than elsewhere, but it is possible that the cavernous texture is in part due to the dissolving out of original quartz. The feldspars are well formed, about equi-dimensional, and will perhaps average about the size of a grain of corn, although they vary from this average considerably in either direction. They appear to be chiefly orthoclase mantled with a thin cover of albite: albite also forms in small separate crystals. The ægirite is dark green in color and in general forms very irregular, prismatic, often tapering crystals which seem to consist of an aggregate of slender prisms. Many, however, exhibit a well-developed prism zone (forms 100, 110), are often twinned (on 100), and not infrequently attain a length of several centimeters. Terminal faces occur but are rare and even on the better crystals are apt to be curiously irregular. Some of the crystals are deeply pitted by solution. In addition to the minerals named there occurs quite abundantly another mineral which appears to be the rare fluo-carbonate of lime and the cerium earths, synchysite, described by Flink from Greenland, where it occurs with a mineral association similar to the Quincy occurrence. The synchysite occurs generally in slender, amber-colored prisms terminated by a basal plane often truncated by the forms of a hexagonal pyramid or rhombohedron or both. The prism zone is deeply striated and has a marked oscillatory development. Zircon crystals are closely associated with the synchysite and are of frequent occurrence. Minute crystals of ilmenite and hematite are occasionally found; also a few minute, black crystals of some as yet unidentified titanium mineral, and two or three small crystals strongly resembling scheelite. Quartz crystals are also found in the pockets. These are more abundant toward the center, while in and along a line of large central pockets the quartz crystals are very numerous and attain a large size. The quartz is in part at least of later age and contains many inclusions of ægirite and secondary hornblende (see later).

The upward extension of this line of large central pockets presents several features of unusual interest. Here are found undoubted fragments of the pegmatitic material first described. Although generally smaller they have been noted as large as 6 or 8 inches in average diameter and are imbedded in a compact, beautifully silky, grayish-blue crocidolite. These pockets also contain great numbers of quartz crystals and a smaller amount of fluorite, both imbedded in crocidolite, which in fact practically fills up the otherwise free spaces. A considerable amount of some other secondary hornblende occurs in the form of exceedingly delicate, black needles in the crocidolite, penetrating the quartz, and in cavities in the pegmatite fragments. The large riebeckite crystals in these fragments are often partially or almost completely eaten out and the cavities then formed may contain later formed quartz and hornblende needles. On one or more faces of the fragments there is usually found a later growth of quartz which took the form of a direct addition to the original quartz of the fragment. The quartz crystals of the pockets vary greatly in size from exceedingly minute individuals to crystals upwards of a foot in length and 3 or 4 inches thick. Many of the smaller crystals are very rich in planes although most of them are curiously irregular, distorted, their surfaces covered with etch-pits, or what in other cases resemble growth-forms. Some crystals have been broken and recemented. Beside the included needles of black hornblende practically all of the quartz is crowded with the crocidolite, which gives it a peculiar bluish color often very attractive. The fluorite has a dark purple color, is beautifully phosphorescent when heated and forms generally in distinct octahedral crystals sometimes an inch or two in diameter. It too has been acted on by some solvent. All stages of solution may be seen to that in which only the mold of the crystal remains containing a mass of fibers originally included in the fluorite. In one large mass of quartz adjoining the line of pockets several good-sized masses of granular galena carrying a little sphalerite and chalcopyrite were found, associated with fluorite and crocidolite.

The pegmatite as a whole appears to be a segregation from the granite characterized by unusual richness (compared with the granite) in certain constituents, notably fluorine, the rare earths, lead, zinc and probably quartz. The crystallization seems to have taken place from the margin inward with certain progressive changes in texture and mineral composition, the central portions becoming as a result increasingly richer in silica, fluorine, the rare earths and the ægirite molecule. The central cavities are thought to be chiefly mariolitic in character, thus allowing a free crystallization. Before the completion of the crystallization there appears to have been a movement in the mass as a whole which resulted in more or less breaking and the formation of fragments found in the pockets. The flow-structure in the dark marginal band about the pegmatite bears out this idea of movement. The residual liquor in the central pockets under the changed physical conditions exerted a solvent action on some, perhaps all of the minerals already formed, and also effected chemical or molecular changes which resulted in the formation of the crocidolite and hornblende needles. Crystallization went on contemporaneously with the above process, although solution seems to have slightly predominated at the end. Surface waters apparently have had but little effect beyond a little kaolinization of the feldspar and oxidation of the iron-bearing minerals.

A closely similar pegmatite, except that the central pockets were lacking, was found about five years ago in the Ballou quarry, located a short distance to the north of the present occurrence. In the Ballou quarry, the pegmatite had the form of a nearly vertical pipe some 2 ft. in diameter and about 50 ft. deep. Many handsome polished blocks were made from this at the time by Mr. F. Wesley Fuller.

It is believed that a more extended study of these pegmatites will furnish much valuable information regarding the chemical composition of the minerals of the enclosing granite and about other problems connected with the interesting riebeckite-ægirite rocks of the Quincy and Blue Hill area.

Laboratory of Mineralogy and Petrology,
Massachusetts Inst. of Technology,
July, 1909.

Art. XLIV.—*Melting Point Determination*; by Walter P. White.

[Introductory.—The recent great advances in pyrometry, together with the development of the electric furnace, have given to many physical and physico-chemical determinations at high temperatures almost the ease and certainty attainable at ordinary temperatures. The appropriate special technic, however, being of very recent development, is not yet generally familiar; the importance, also, of the whole new and fertile high-temperature field is still growing in appreciation. It has therefore seemed wise that the methods developed at the Geophysical Laboratory be published from time to time for general information, aside from their immediate application to our own work. In pursuance of this idea, two special papers have already been published, treating of furnace construction and of temperature measurement up to 1600° C.* The present two papers deal with the application of such measurements to those methods of physico-chemical thermal analysis which, best known through their revelations of the constitution of metallic alloys, are now being applied with equal success to the minerals and allied compounds. The first treats of melting phenomena in general, and its conclusions are not restricted to the high-temperature field. The second describes the furnace technic used to realise the conditions treated in the first.]

Fig. 1.

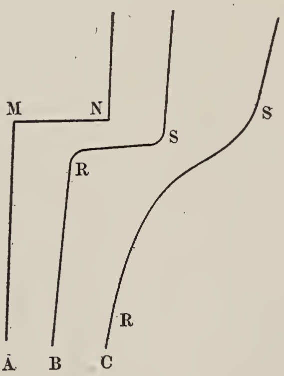


Fig. 1. Melting curves. A, ideal; B and C, actual curves for silver and anorthite, reduced from Day and Allen, Isomorphism and Thermal Properties of the Feldspars.

The preëminent value of melting ice as a temperature standard has made familiar the great constancy of the ideal melting point and its independence of external temperatures. The great majority of actual melting point determinations, however, fail to show this ideal constancy, and display a melting interval, rather than a point. If the temperature-time curve, A (fig. 1), represents an ideal

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* Day and Allen, Phys. Rev., xix, 177, 1904; W. P. White, Phys. Rev., xxv, 334, 1907. Other papers from this laboratory incidentally treat of methods, but in this respect are largely summarized (as well as supplemented) by the present papers.

melting under uniform heat supply, with MN as the interval of constant temperature, the actual result with a substance melting at high temperature more nearly resembles the *oblique* curves B and C, where the temperature intervals RS may be as much as 60°.

When the melting curve is oblique, there is a much greater opportunity for both accidental and systematic errors. In our own work these have not been serious, considering the high temperatures concerned, and were for a long time far less uncertain than the extrapolated temperature scale itself. The greatest discrepancy in a set of determinations of the same point has seldom reached 3°.*

But other observers had found much larger and sometimes confusing irregularities, and had questioned the value of the thermal (Frankenheim) method of determining melting points; moreover, the causes for the obliquity of these melting curves were in themselves of interest; and finally, in investigations on some pyroxenes, a problem was encountered which called for much more accurate comparative measurements than we had been getting. A general investigation was therefore undertaken of the thermal method of determining melting points, with the twofold object of learning more about the properties of matter in the vicinity of the melting temperature and of improving our own technic. As a result, the agreement of our silicate determinations has been increased about five-fold,† along with an actual gain in case of experimental manipulation. An insight into the relations involved has also been obtained which has cleared up several questions once very puzzling, and has pointed the way to a further increase in accuracy whenever this seems necessary.

A number of substances, organic and inorganic, melting at temperatures from 0 to 1400°, were examined under various conditions. Most of these experiments were devised to test hypotheses and need not now be described in detail. The conclusions to which they led will perhaps also gain if presented in a different order from that of the actual investigation.

To fix the ideas, it may be well to recall at the outset the general plan of the experimental arrangement used in our regular work, to which this article more directly applies. The substance to be melted is contained in the crucible (fig. 2).

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* It may make for clearness to emphasize at the outset that the errors considered in this paper, which the investigation here described sought to diminish, are errors of 5° or less, occurring in the regular work of this laboratory upon silicate fusions. With the systematic differences of 100° to 200° sometimes occurring in the literature, this paper has nothing to do.

† This improvement has already been illustrated in a paper on Diopside and its Relations to Calcium and Magnesium Metasilicates, this Journal (4), xxvii, 4, 1909.

In the middle of the charge is the thermometer, which in our case has always been a thermoelement of some kind. This is sometimes used bare, sometimes surrounded by porcelain and platinum jackets, as here represented. The crucible is heated by an electric resistance furnace, for which a storage battery furnishes a very regular source of heat. An additional control element, C, indicates the furnace temperature, and also, if desired, permits of regulating it.

Fig. 2.

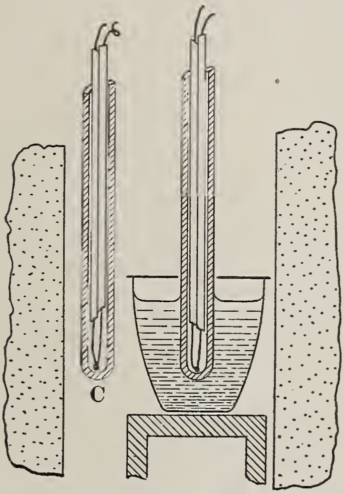

Fig. 2. Sectional view of ordinary melting point apparatus (half size). C, control element.

It is a familiar fact to workers in this field that freezing points are often sharper and show much better agreement than melting points. The reasons for this difference occupy much of the present paper. One result of it is that freezing point determinations are generally preferred, and most of the literature of the subject relates to observations made with falling furnace temperature. Freezing points, however, are uncertain or useless in substances where undercooling is marked or crystallization sluggish. Since this is nearly always the case in silicates, the melting point, in spite of its greater experimental difficulty, is the only one used in our silicate work, and is the point mainly in view in this paper. The special disadvantages of the melting curve would no doubt be largely overcome by stirring, but effective stirring is difficult in many cases, impossible in the rest, and has never been attempted here.

The principal causes of oblique melting curves appear to be the following:

A. Primary, i. e., inherent in the substance itself.
  I. Time lag in the melting process (with very viscous substances).
  II. The presence of impurities.
B. Secondary, i. e., due to a failure of the apparatus to register truly the behavior of the substance.
  III. Inconstant heat supply.
  IV. The normal temperature gradient between the outside and inside of the melting charge.
  V. Accidental irregularities in temperature distribution.
  VI. Flow of heat along the thermoelement.
  VII. Electrical conductivity of the charge (in case the thermoelement is used bare).
  VIII. Inhomogeneity of the thermoelement.
  IX. Differentiation of the charge in crystallizing.
  X. Radiation through the melting substance.

I. *Viscosity.*—Day and Allen* discovered that albite and orthoclase exhibit a sort of hysteresis in their melting, and the same thing has since been found true of quartz. It is connected with the great viscosity of the melted substance near its melting point. The change of state takes place gradually, even at temperatures many degrees (100 or more) above that at which it will also occur, if time enough is given. Theoretically, this effect must probably be regarded as characteristic of all substances, though of course it is too small to be perceived in most. That it might generally be large in silicates, however, did not at first seem at all unlikely, but such is not the case. Although considerable portions of a charge of albite or orthoclase may remain unmelted after several hours exposure at a temperature 150° or more above the point where melting begins, diopside (to take one instance) has been heated three times at rates varying from 4° to 13° per minute with results agreeing to ·1°. (The distinguishing sign of the presence of this phenomenon is of course the variability of the melting temperature with the rate of heating.) Hysteresis in melting, therefore, is only an occasional cause of obliquity in melting curves.†

II. *Impurity.*—The effect of impurity in diminishing the sharpness of melting points is fairly familiar, especially to organic chemists. But the character of the effect on the temperature-time curve seems to have been little appreciated, and its importance and magnitude have often been underestimated.

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* Isomorphism and Thermal Properties of the Feldspars, Publication No. 31, Carnegie Institution of Washington, pp. 50-54; this Journal (4), xix, pp. 119-125, 1905.

† If the hysteresis *is* large, however, the melting point procedure evidently needs radical modification. See the next article, p. 483.

It is, in fact, a direct result of the melting point lowering due to the impurity, and an expression for it can be derived from the law of the lowering. This takes a very simple form for the most common and important case, namely, that in which the depression of the melting point is proportional to the amount of impurity. A discussion of this case will serve to show the usual character of this important effect.

In order to define a melting point curve, two quantities are necessary, and usually sufficient—the temperature rise ($d\theta$) and the quantity of heat (dQ) required to cause it. Indeed, the true melting point curve is only the graphic expression of the relation between these two, that is, of the quotient $\frac{d\text{Q}}{d\theta}$. When the temperature rise is plotted against time, the time really serves only as an approximate measure of the added heat. $\frac{d\text{Q}}{d\theta}$ is, however, by definition, the specific heat.* Hence a melting body as a rule is completely accounted for thermally if it is treated as a body of enormously variable specific heat, and this is often the simplest and easiest way of dealing with it.

The effect of impurity, then, on the melting curve is its effect on the quotient, $\frac{d\text{Q}}{d\theta}$, which is found as follows for the case where the melting point lowering is proportional to the amount of impurity present.

Let the melting point of the perfectly pure substance be taken as the temperature zero; (the temperatures during melting will then be negative and will decrease numerically as the substance becomes hotter.) Let θ_0 be the lowering of the melting point in the actual case. The temperature, θ_0, is then the temperature at which the impurity present has just sufficient concentration to bring the whole mass of solvent into fluid condition. Next, let half the solvent be crystallized by lowering the temperature. The concentration of the impurity is now double what it was before, and the lowering of temperature by hypothesis also double, or equal to $2\theta_0$; similarly, one third of the solvent will remain liquid at $3\theta_0$. Or, if A is the fractional part of the solvent left in a liquid form, $\text{A} \propto \frac{1}{\theta}$. This may be written $\text{A} = \frac{\text{K}}{\theta}$ where K is a constant to be determined.

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* $\frac{d\text{Q}}{d\theta}$ may, of course, also be so measured as to equal the heat capacity. As the two are proportional to each other for the same charge, the distinction is of no importance here.

Now the rate of absorption of heat by melting, that is, the portion of $\frac{dQ}{d\theta}$ required for the melting, is proportional to the amount melted per unit rise in temperature; that is, proportional to $\frac{dA}{d\theta}$, or, say, *equal* to $m\frac{dA}{d\theta}$, where m is merely the factor of proportion. But $\frac{dA}{d\theta} = -\frac{K}{\theta^2}$, and since the integral of $m\frac{dA}{d\theta}$, that is, the integral of $m\frac{K}{\theta^2}$, from θ_0 to ∞, must equal the latent heat, L, therefore mK is equal to Lθ_0. Accordingly, if S is put for the true specific heat at any temperature, the total virtual, or apparent, specific heat, Σ, is

$$\Sigma = S + \frac{L\,\theta_0}{\theta^2} \tag{1}$$

for temperatures below and not too far from θ_0. Through most of the interval where the equation can be used, S is relatively so small as to be usually negligible and the function may then be written simply,

$$\Sigma = \frac{L\,\theta_0}{\theta^2} \tag{2}$$

The form of the resulting melting curve can now be obtained by writing $\frac{dQ}{d\theta}$ for Σ and integrating from θ_0 to θ, giving

$$[Q]_{\theta_0}^{\theta} = (S + \frac{L}{\theta})\,(\theta - \theta_0) \tag{3}$$

from which Q can be obtained in terms of θ. If (2) instead of (1) is used,

$$Q = L - \frac{L\,\theta_0}{\theta} \qquad \text{whence}$$

$$\theta = \frac{L\,\theta_0}{L - Q} \tag{4}$$

from which θ can be plotted in terms of Q. Here θ is still measured downward from the true melting point, and Q is really the amount of heat given out as the body freezes. But of course this expression gives the form of the curve as well as any, and is simpler than one with positive temperatures and heat quantities would be.

Such a curve is the smooth curve of fig. 3. The circles mark a curve actually observed near 900° in a case where all other sources of obliquity were practically eliminated.

The recognition of the part played by impurity changes radically the ordinary conception of melting point phenomena.

Instead of a constant temperature, the observer has to deal with one varying continually from beginning to end.* The course of the phenomenon, so far from being independent of the furnace temperature, follows it closely and registers its every fluctuation.—Some consequences of this point of view deserve discussion.

Fig. 3.

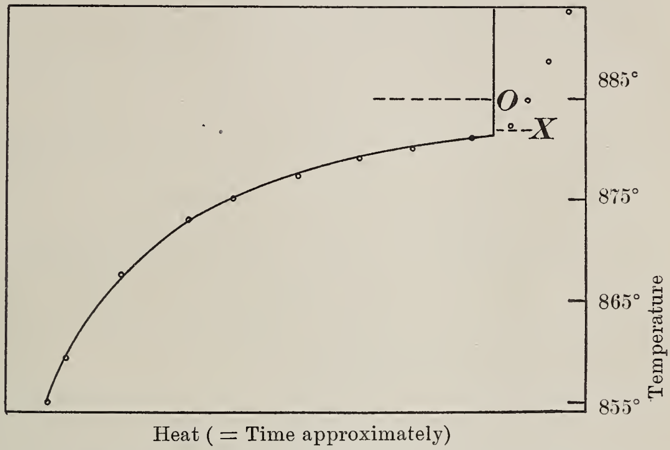

Fig. 3. Typical melting curve. Points taken from an observed curve for Na_2SO_4 containing $\frac{1}{3}$ per cent NaCl. X–O, melting point depression below pure substance. Smooth curve calculated by formula 3 for the depression, X–O. Data page 484.

1. *The accuracy of the thermal method.*—The obliquities of thermal curves have been cited by several observers as an evidence of the inaccuracy and untrustworthiness of the thermal method. Rather are they the very sign of its fidelity to the phenomena. If a method could be devised which gave perfectly sharp points in ordinary substances, it would by that very fact be convicted of misrepresenting the facts and of consequent untrustworthiness. And while the method, for instance, of locating the melting temperatures by watching for changes in the appearance of the charge shows in a way the gradual progress of the melting, its results are much further removed from the quantitative. There is no definite connection between the amount of material melted and the appearance of the charge to the eye. The thermal method alone at high

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* The fact that a melting interval and not a melting point is really in question has been recognized by some observers, who regularly determine the upper and lower limits of this interval. It is clear, however, from the discussion above that the assignment of any lower limit is entirely arbitrary.

temperatures contains the possibility of tracing exactly the progress of a melting from beginning to end.

2. *Variation of the obliquity with temperature.*—In accordance with the familiar formula, $\Delta = \frac{\cdot 02\theta^2}{L}$, the melting point depression, Δ, is proportional to the square of the absolute temperature and therefore (see equation (3) for instance) the melting curve obliquity must vary in the same way. Hence the large effect produced at high temperatures by amounts of impurity which would be quite negligible lower down. Thus, to take a roughly approximate illustration, ·1 per cent of an impurity of molecular weight 80, say CaF_2, dissociated to double the number of molecules, would by the formula lower the normal melting point (1392°) of diopside 1·3°, and would cause an apparent doubling of the specific heat 20° below that, while if the equation (1) held strictly, the beginning of the melting would be easily perceptible 50° lower still. A similar impurity would lower the melting point of ice only ·05°, and the doubling of the apparent specific heat would occur within 3° of the melting temperature.

These facts have a direct bearing on the question of the value of melting point determinations in natural minerals. While the impurities of natural minerals in rare cases run within a few parts per thousand, they are usually to be reckoned in per cents. But one per cent of impurity may be expected to lower the melting point from 3° to 10° and extend the distinctly perceptible melting interval over some 100°. And silicates with 3 per cent of impurity usually show in most decided fashion the characteristic behavior of two-component systems.

3. *Experimental determination of the quantity of heat supplied to the charge.*—A quantitative knowledge of the heat supply is evidently essential to a correct melting curve. The use of time as a measure of it, which forms the basis of nearly all the common melting point methods, is recognized as merely a rough approximation,* and would not have answered at all in most of the cases here treated. Hence a more accurate method was employed. It rests on the use of the control element, C, fig. 2, which allows a determination of the temperature difference of furnace and charge, on which, and not on the temperature of either alone, the heat flow directly depends. This method is more fully treated in the second paper, p. 485.

4. *Single melting points.*—In most determinations on melting substances, the melting temperature is the sole object of

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* G. K. Burgess, Methods of Obtaining Cooling Curves, Bull. Bur. Standards, v, 223, 1908; W. Rosenhain, Observations on Recalescence Curves, Proc. Phys. Soc. London, xxi, 183, 1908.

investigation. This temperature, θ_0 of the formula, is the upper end of the melting interval, the point X of figs. 3 and 4. The other characteristics of the curve, the values of the specific heat, etc., are then, at most, questions of minor interest. Nevertheless, in such cases the complications due to impurity are as important and as troublesome as anywhere. For in an impure substance the melting temperature desired is merely one value of a continually changing magnitude. Before it can be measured it must first be located on the oblique curve. But, coming as it does at the top of the melting interval, and therefore at the end of the melting, it falls where the temperature changes are most irregular, disturbed and uncertain of interpretation. The resulting difficulties occupy the rest of this paper. Meanwhile, a glance at fig. 1 shows the difficulty which may arise in locating the single melting point.

III. *Varying rate of heat supply.*—In determining the single melting *point* of an ideally pure substance, the character of the heat supply is a matter of indifference so long as it does not approach zero or infinity. For the exact determination of the melting *curve* of an impure substance, the heat supply must be well known, as has just been seen. For determining the single melting point of a rather impure substance an intermediate condition obtains. The heat supply need not be known and need not be constant so long as its variations are regular. That is, the "break" will show on almost any *smooth* curve. The determination of a melting point with a varying heat supply, however, often gives rise to a secondary phenomenon so striking and so apt to be misleading as to deserve mention here. This occurs when the furnace rate is kept nearly constant, as it usually is. As soon as the charge begins to melt, its temperature rise is checked, so that the continued advance of the furnace widens the gap between them; thus the constant rate of the furnace necessarily involves a very variable rate of heat supply to the charge. The result is to hurry up the latter end of the melting, apparently increasing its obliquity. The same happens at the end of a freezing curve, if such is taken. But the end of a melting curve is the top, of a freezing curve the bottom; hence the two kinds of curves are distorted out of all resemblance to each other, the melting curve appearing more, the freezing curve less, oblique in the upper part than it really is. The observer who, attempting to secure constant conditions, approaches his melting or freezing determinations at the same rate, and then maintains this rate constant in the furnace, is likely to go through the critical part of his melting curve five to ten times as fast as he realizes. If, however, the initial rate is then adjusted by trial so as to give satisfactory results at the end of the melting, the only disadvantage will be the loss of time in taking the first part so slowly; and this may sometimes be less objectionable than the remedy—which is, to make separate observations on the furnace temperature and thus keep the external temperature gradient constant.

Heat Distribution Within the Charge.

The next three causes of obliquity constitute the chief practical problem in melting point work. They depend upon differences of temperature within the charge and could be avoided if thorough and effective stirring were possible. They are less detrimental in the determination of freezing than of melting points, and are less also in metals whose high thermal conductivity is in part a substitute for stirring. To them it is due that, other things being equal, the melting point of a salt usually cannot be determined quite as accurately as that of a pure metal or as its own freezing point. They may, however, be greatly diminished by proper experimental arrangements.

IV. *The regular and normal temperature gradient across the charge.*—The error and uncertainty resulting from the failure to stir has often been greatly overestimated. The charge as a whole may present great temperature differences, but the thermoelement does not record all these at once. It accounts only for the portion immediately surrounding it, and when this portion melts it will show a "break" in the temperature curve. Toward this small system of element and surrounding material, the outer portions of the charge act in many respects as so much foreign matter—though foreign matter which is particularly troublesome, on account of its own heat absorptions. Their effect can be investigated with quite enough exactness for the present purpose, by the device already used, of treating the melting charge as a body of variable specific heat.

1. *Expression for the temperature distribution in an ordinary charge.*—As a heated charge is brought toward its melting point, the supply of heat is usually constant, and then the rate of temperature rise, $\frac{d\theta}{dt}$, soon becomes the same at all points. The resulting temperature distribution at any instant may then be found to a sufficiently close approximation as follows: Suppose, first, that the body is spherical with a radius equal to R, and the heat flow is entirely along radial lines. Consider a spherical surface, A, at a distance, r, from the center of the sphere. Its area is $4\pi r^2$; the inclosed volume $\frac{4\pi r^3}{3}$. The flow of heat across it may be expressed in two ways: (1) Directly, as the product of area, conductivity and tempera-

ture gradient, that is, as equal to $4\pi r^2 K \frac{d\theta}{dr}$; and (2) as the heat absorbed by the inclosed volume, or the product of volume, volume specific heat, and the rate of temperature rise, equal to $\frac{4\pi r^3}{3} S \frac{d\theta}{dt}$.

Equating these two and integrating, remembering that $\frac{d\theta}{dt}$ is here a constant, we have

$$\Delta\theta\Big]_r^R = \frac{S}{6K}\frac{d\theta}{dt}(R^2 - r^2) \qquad (5)$$

If the charge is an infinitely long cylinder, we have the same expression with 4 substituted for 6 in the denominator of the second member. In general, we may say, therefore, that the temperature gradient within a uniform, solid, steadily heated charge approximates a parabola, and the difference of temperature between center and outside for bodies of the same shape is proportional to the *first power* of the rate of heating and to the *square* of the diameter.

If we let $\delta\theta = \Delta\theta$, then δt is the time required for a given temperature value to pass from R to r,—that is, it is the *time lag* of r behind R. It equals

$$\frac{S}{6K}(R^2 - r^2) \qquad (6)$$

It is independent of the rate and is thus important as a property of the charge alone.

2. *Effect of the melting on the temperature distribution.*—In an actual melting point determination one fundamental hypothesis of the preceding no longer holds. The temperature rise of the charge is not regular after melting begins. We may, however, still proceed for the case of a small charge, for which the time required to reach an equilibrium temperature distribution will be relatively small, so that the divergence from such a distribution may be neglected in making the first approximation. Mathematically, the problem then reduces simply to finding the effect of a change in the specific heat, the rate of heat supply, $\frac{dQ}{dt}$, remaining constant. This is easily done as follows: Since

$$dQ = S d\theta$$

$$\frac{d\theta}{dt} = \frac{dQ}{dt} \cdot \frac{1}{S} \qquad (7)$$

If, therefore, the specific heat S increases n times, becoming nS, the rate, $\frac{d\theta}{dt}$, will evidently *diminish* n times. The time lag (equation (6)) will *increase* n times. The temperature distribution can be found by substituting from (7) in (5). The result is:

$$\Delta\theta]_{\frac{dQ}{dt}\,\text{const}} = \frac{dQ}{dt}\,\frac{1}{6\text{K}}\,(\text{R}^2-r^2) \qquad (8)$$

In this expression the specific heat does not appear at all. The equilibrium *temperature* distribution, therefore, is not altered by a change in the specific heat. Among these results of a change in specific heat the increase of the time lag is of most immediate interest. Occurring under constant heat supply to the whole charge, it involves a retardation in the supply to the center, and one which is proportional to the square of the radius. The formulæ thus express in a roughly quantitative way the otherwise obvious fact that as the melting begins the inner layers fall behind, since the outer layers for a time absorb large quantities of heat, passing very little to the interior. Expressed in terms of temperature, the retardation will be $n-1$ times the (original) time-lag times the rate.

This result, however, as already indicated, applies strictly only to an infinitesimal charge, since it assumes a complete homogeneity, which the melting itself destroys. In the actual case, while the body is melting the outer layers will have a higher temperature and therefore a greater specific heat than the inner. This, it can readily be shown, will diminish the temperature difference between center and surface and therefore the time lag, while an increase of conductivity due to melting will probably act in the same direction. The retardation of the center will thus really increase less rapidly than the square of the radius, and for a very large crucible will not even approach the formulæ just given.

As soon as the outward layer of the charge is fully melted, the whole course of the phenomena changes. The virtual specific heat of the substance while melting is usually from 50 to 100 times what it is before or after, hence the heat capacity of the whole depends for a time almost entirely on the still unmelted core. As this diminishes the *relative* heat supply to it increases, increasing the obliquity of the critical end-portion of the curve. Nor is the resulting distortion, like that from uneven heat supply, above described (page 461), merely a general increase in steepness at the end. It is a rapidly accelerated increase, changing the form of the curve in that region. In large crucibles, it often masks entirely the break at the end of the melting, substituting for it a premature break a degree or two *lower down*, due to the rapid increase in heat supply before the melted layer has touched the thermoelement at all.

In brief, then, the inevitable heat distribution in an unstirred charge has this effect on the center, where the thermoelement is located. It retards the normal temperature rise at the beginning of the melting and partly makes up the loss by accelerating it at the end, thus increasing the obliquity of the curve just where such increase is most undesirable. This effect increases somewhat less rapidly than the rate of heating and than the square of the diameter. The difference of temperature between center and surface remains nearly constant for small crucibles, but diminishes during melting for large diameters and rates.

3. *Magnitude of the distortion.*—Diopside, a well-crystallizing silicate, melting at 1392°, showed a time lag of 24±6 seconds for a crucible of 1^{cm} radius before melting began. The charge was in shape a short cylinder. The latent heat was enough to raise the solid over 300°, but was so distributed that the maximum value of the virtual specific heat was only about fifty times the true specific heat.

If, now, this substance is heated in a crucible of 1^{cm} radius with a constant heat supply, giving a temperature rise before melting begins of 8° per minute, the melting will last (roughly) thirty-five minutes. The time lag (surface to center) would by formula (6) reach twenty minutes for a charge all at the maximum specific heat, but in this case, as experiment shows, will be not much over half that. Even so, however, the period of accelerated heat supply to the center will last ten minutes, so that the last third (or more) of its melting will be distorted. This third covers an interval of 2 to 3°. The resulting uncertainty in the melting point would be less than that, and, therefore, not very serious, but with a crucible of 4^{cm} diameter the uncertainty would be much increased.

If the crucible has 1^{cm} diameter ($\cdot 5^{cm}$ radius), the maximum lag by formula (6) is only five minutes, or one-seventh the melting interval, and the whole accelerated interval is not over half a degree. If this smaller crucible, however, contains a substance of greater purity, say sodium chloride, melting through a 1° interval, the virtual specific heat might reach 400 times the true, and the accelerated interval would again cover a third or more of the melting.

The distorting effect produced on the melting curve by the normal gradient through the charge is, then, practically important only in large charges, and though serious in them, can be rendered negligible by a reduction of dimensions which is easily attainable in practice. The distortion is also relatively greatest in the purest substances, where the total obliquity is least detrimental.

For naphthaline, the time lag was about three times that for diopside. For metals, the conductivity is so great that distortion of the kind just considered is probably always negligible in practice.

4. The above seems to justify the following practical conclusions: (1) *For determinations of single points*, the essential thing is to reduce the interval of accelerated heat supply. This calls for small crucibles or slow rates. And when they are used, the difficulties arising from the regular temperature gradient across the charge can be rendered negligible compared to other sources of error. The requirements of a given case depend on the accuracy desired and on the purity of the substance, and can be determined well enough for all practical purposes from the length of the melting interval in conjunction with the approximation just given for the relation of time lag to radius in different substances. (2) *For determining the form of the whole melting curve*, the time lag must be kept small, and this again calls for the narrow crucible but not the slow rate, for a reason given in the following paper (p. 485). (3) Whether rate or radius, or both, shall be diminished will depend mainly upon the apparatus and conditions at the disposal of the investigator. The whole time required to complete the melting varies nearly as V, the rate of heating. The distortion varies as R^2V, but V varies as G/R, where G is the external gradient, hence the distortion varies as GR also. And, therefore, for the same distortion by diminishing R, V and G are both increased. So if R is made, say, one-third, the run may be finished in one-ninth the time, and the effect of variation or uncertainty in the furnace temperature also diminished three times, with little increase in distortion.

V. *Irregular variations in heat distribution.*—The preceding section has dealt with an ideal case. It assumes a charge in which the heat travels uniformly toward an infinitesimal thermoelement situated exactly at the center.. Of course these conditions are never completely realized.

Sources of irregularity may lie in the furnace, in the charge itself, or in imperfect centering of the thermoelement. Aside from these, there is nearly always a tendency for melting to start at one end of the charge, either top or bottom. In any case, the difficulty comes mainly from the fact that the melted area reaches some parts of the thermoelement before others, so that the temperature of the junction depends on different portions of the charge, some of which are melted while others are not. This converts the ideally sharp break (X, fig. 3) into a gradual rise, of uncertain interpretation. To avoid this difficulty, two things are necessary. The thermoelement itself should conduct heat as little as possible, and the melting should approach it from the side and not from the end. This calls for a thermoelement of fine wire, and for a charge narrow but not too short. Failure to center the thermoelement is evidently a minor fault. A thermojunction inclosed in a porcelain tube is from the present point of view undesirable, since its temperature is dependent on a considerable portion of the charge. A resistance thermometer is evidently still worse. In fact, the difference in sharpness is very marked between melting points measured with an inclosed and a bare thermoelement. But a bare element of platinum wire $\cdot 6^{mm}$ in diameter, immersed 8^{mm} in a cylindrical charge of 9×14^{mm}, has been found to give (from 800° up) points quite as sharp as can be obtained with wire much smaller. Since finer wire than this and narrower and higher charges can be easily used, there seems to be no difficulty in avoiding the effect of irregular temperature distribution for substances in which a bare element is admissible. A few experiments indicate that at lower temperatures charges narrower in proportion to their height may perhaps be needed, but at lower temperatures they can also easily be employed.

VI. *Conduction of heat along the thermoelement.*—The thermal conductivity of most substances is much less than that of the metal thermoelement, so that the junction often receives heat along the wires. This causes a gradual additional rise of temperature toward the end of melting, thus increasing the obliquity, and it also tends to make the final break come high. The effect is little altered by change of rate, since this acts in the same way upon the heat, whether coming through the charge or down the wire. It increases with the diameter of the charge, since this increases the time of melting for the same external gradient. It is diminished by thinness of the thermoelement, and by depth of immersion in the charge. The avoidance of this cause of obliquity, then, demands the same conditions as for the preceding, namely narrow and high charges and fine thermoelement wires. And the experience just now cited to show that the one cause of obliquity can be easily avoided is equally conclusive with respect to the other. On the other hand, an enclosed element, immersed 3^{cm} in a crucible of sodium chloride, gave a melting point 7° too high. This error is much greater than that found with some other substances melting at higher temperatures,* but it shows that melting point results obtained with inclosed thermoelements must be interpreted with care. A sufficient estimate of the error resulting from heat conduction down the thermoelement can in general be easily reached by varying the depth of

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*See, e. g., Isomorphism and Thermal Properties of the Feldspars, pp. 23–25; Diopside and its Relations to Calcium and Magnesium Metasilicates, pp. 3–4, loc. cit.

immersion. This method applied to 2·5 gram silicate charges indicates that there was no perceptible error of this sort with the element immersed 6 to 8^{mm}, thus confirming the results obtained by varying the size of wire.

VII. *The use of bare thermoelements.*—From the foregoing it is clear that in several ways a very great advantage results if the thermoelement can be inserted directly in the charge. But an error may then be introduced, due to the electrical conductivity of the charge itself, which can not be altogether neglected. At high temperatures, practically everything conducts electricity to some extent.

The slightly conducting charge acts like a battery of very high resistance connected in shunt across the junction.* The effect on the galvanometer reading of such a battery is easily shown to be practically equal to $E_s \frac{T}{S}$, where E_s is an E.M.F., T, the (very low) resistance of the shunted portion of the thermoelement, S, the (very high) resistance of the shunt. It follows, first, that the leakage error increases with the depth of immersion of the thermoelement and the fineness of its wires, and second, that by dipping into a charge portions of a thermoelement far from the junction the effect can be magnified, and so a very delicate test made for it. Indeed, for this test there need be no junction at all; if there is one, either it can be kept at room temperature, or its E.M.F. can be measured by making it also the junction of two other wires which do not dip in the charge. In these ways it has been shown that the error due to this effect, under the conditions of our work, is not over one or two-tenths of a degree, either in sodium chloride near 801° or in diopside near 1400°. It was also shown, in the case of sodium chloride melted in a crucible over a Bunsen burner, that the E.M.F. is thermoelectric and is directed (in this case) from the electrolyte to the colder of the two wires. Hence the error increases with the temperature differences present in the charge. The convection currents of a large charge frequently reveal their presence through the slight unsteadiness of the galvanometer, and in one case the leakage disturbance from melt conductivity was increased a hundred-fold by bringing a charge too near the furnace top.†

The conditions making for small leakage error are therefore: Uniformity of external temperature, smallness of charge, and thickness and shortness of the immersed portion of the thermo-

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* The effect would of course be the same if it were connected across any other portion of the circuit.

† It is therefore clear that the results just quoted as to the very small error from conductivity of the melt should be applied with great caution in extreme cases.

element. These are in part antagonistic to those required for diminishing effects V and VI, but with apparatus of the dimensions given above, page 467, all these errors are reduced to one or two-tenths of a degree or less.

MINOR CAUSES OF OBLIQUITY.

VIII. *Contamination of the thermoelement.*—If the furnace is heated continuously and more or less regularly throughout the melting interval, the temperature of the furnace end relatively to the charge steadily rises, and if the thermoelement is not homogeneous between these two, its reading will rise also.* In the case of a badly contaminated element at 1400°, this apparent increase of obliquity was found seldom to exceed 1°. It practically vanishes if a constant temperature difference is maintained between furnace and charge, as also of course if the element is in good condition; hence, while not to be overlooked, it should never constitute a serious difficulty.

IX. *Differentiation in the charge.*—The portions of an impure charge which crystallize last may have more impurity in them, hence there may be a tendency for that part of the charge immediately around the thermoelement to melt at a lower temperature than the outside. This would tend to increase the obliquity of the observed curve. Thus far, we have not been able with certainty to distinguish this effect from the other accompanying causes of obliquity.

X. *Radiation through the charge.*—If the charge which is being melted is diathermanous, direct radiation from the crucible wall to the thermoelement will heat the latter, causing a temperature rise which is greatest at the beginning of the melting and which depends upon the fluctuations of the furnace temperature. This effect, also, has not yet been distinguished with certainty.

PRESENT STANDING OF THE PROBLEM.

Fig. 4A shows the typical melting curve of a fairly limpid silicate (diopside). That the obliquity in the lower part of this and similar curves is due to the substance itself (and therefore to impurity) can be easily shown as follows: The obliquity always precedes the melting, wherever that may occur, hence it is due to the melting in some way or other, and not to the furnace; that is, it indicates a true heat absorption accompanying the melting. When the heat absorption begins, the thermoelement in the charge reads about 30° lower, and a bare element exposed directly to the furnace outside the charge reads (usually) 25° lower than the final melting point. Hence

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* Phys. Rev., xxvi, 535, 1908.

no part of the very small charge can then be at or near the melting point itself. And therefore some heat absorption due to melting must occur at least 20° below the melting point. The obliquity is also, within the experimental error, such as would be expected from the known impurity, and can be increased in silicates, and produced in substances originally pure, by the addition of impurity.

Fig. 4.

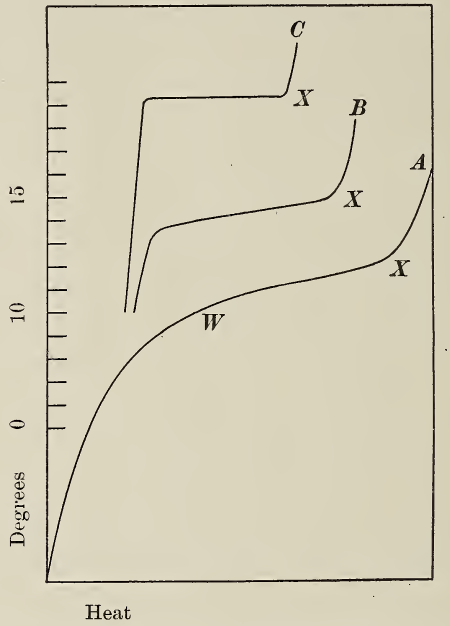

Fig. 4. Actual melting curves. *A*, Diopside (melting point 1392°). *B*, NaCl (melting point 801°). *C*, Na_2SO_4 (melting point 885°) (see text pp. 469–471).

The slope of the curve at the top from W to X is inconsistent with equations (1) to (4) and is not easily accounted for by any other known impurity effect. An attempt was made to determine its cause. Variations in rate of heating, in the depth to which the thermoelement was immersed, and in the size of the wire, did not materially alter this part of the curve, thus showing that neither distortion (effect IV) nor conduction down the thermoelement (VI) was responsible.

An easily crystallizing substance was next tried. Sodium chloride (freezing point 801°±1°)* gave the curve B in fig. 4, which shows the same peculiarity. Variation of rate and of

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* This is a new determination.

size of thermoelement wire did not affect it perceptibly. The freezing point here lay below the melting point as determined from the curve. Hence in this case, the slope of the upper end of the curve is due to the temperature measurement and causes the melting point to come a little high. Presumably the same thing is true of the silicates giving curves like A of fig. 4. In fact, the results obtained by adding different amounts of impurity to one of these silicates are much more consistent with each other and with equation (1) if the melting points are taken a degree or so lower than indicated by the curves.

Sodium sulphate† (melting point 885°±1°)* was then tried. The resulting curve is C of fig. 4. The whole melting interval was ·1° in one charge, ·3° in another, which probably became slightly contaminated in handling. For a temperature so high, this is a remarkably sharp curve. Taken with the preceding it indicates that the false rise at the end of the melting may be avoided, and that a clue to its cause may be found in the physical differences between sodium sulphate and sodium chloride at their melting points. A further investigation of the problem seems to require apparatus not now at hand. Meanwhile, the systematic error for the melting point determination in a limpid silicate has been reduced to a degree or so, and the accidental variation to half a degree, and this accuracy is obtained with exceedingly simple and convenient apparatus. The error in the true melting point of these silicates due to impurity is (in our case) quite as great as (and opposite to) the experimental error. An attempt to realize greater accuracy, probably attainable only through more elaborate experimental arrangements, has not seemed necessary at present.‡

The addition of impurity to the sodium sulphate of fig. 4, C, gave the typical oblique curve of fig. 3.

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* This is a new determination.

† From J. T. Baker Chemical Company, who gave the following analysis: Ca, ·005 per cent; Mg, none; Fe, ·0006 per cent; Cl, trace.

‡ In the work on Diopside, etc. (this Journal, xxvii, 8, 1909), the melting points of the eutectic in different mixtures of pseudowollastonite and diopside are not quite the same, as by theory they should be, but rise with the percentage of eutectic present, varying about 6°. The variation, though far within the limits of error of most previous determinations at this temperature, is consistently greater than the accidental variations of our results. Two causes for it are indicated by the present article: (1) Where the percentage of eutectic is larger and the time of melting, therefore, longer, the false rise at the end of the melting curve is greater. These results are therefore a little too high. (2) Where the amount of eutectic is small the total impurity present bears to it a larger ratio, and there is thus a tendency for the melting point lowering to be increased—these results are thus a little too low. It is probable that both causes are operative.

Hüttner and Tammann* point out the connection between impurity and the obliquity of the melting curve, here developed in equations (1) to (4), and suggest that the form of the curve may be a convenient means of estimating non-isomorphous impurities. They give a numerical computation for the last half of the melting interval (or the first half of the freezing interval), but appear to have overlooked the result which would be obtained by carrying their calculation farther down the curve, for they have no other explanation of the large obliquity usually found there than conduction of heat along the (bare) thermoelement, which they assign as the principal source of obliquity. Their view as to the practical cause of such obliquity is thus decidedly opposed to that reached in the present investigation.

Summary.

1. Actual melting and freezing point curves are nearly always oblique—that is, they show, not the constant temperature called for by elementary theory, but instead, an interval within which the temperature continuously rises or falls.

2. The prime cause of obliquity in melting curves is the obliquity of the melting itself, due to impurity. The true melting point is the high end of the oblique melting interval.

3. The melting hysteresis of some very viscous substances (mostly compounds of boron and silicon) is also an occasional (and then serious) cause of obliquity.

A number of causes of obliquity lie in the experimental determination of the behavior of the melting and freezing substance.

4. The determination of a melting curve necessarily involves two factors: temperature rise, and heat supply; the latter depends on the temperature difference of furnace and melting charge; if this varies, the curve is distorted in a way striking but easy to correct. The most common and conspicuous example is where the furnace temperature is allowed to rise or fall continuously, while the substance, melting or freezing, remains nearly stationary.

5. The freezing point, coming at the beginning (in time) of the interval, where temperature distribution in the charge is relatively uniform, is easier to observe than the melting point, but is inadmissible in substances where undercooling is marked.

6. The melting point, coming at the end (in time) of the interval, is liable, where stirring is not practiced, to obliquities resulting from uneven temperature distribution: First, due to the inevitable temperature difference between inside and out-

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* K. Hüttner and G. Tammann, Über die Schmelzpunkte und Umwandlungspunkte einiger Salze. Zeitschr. f. Inorgan. Chem., xliii, 218, 1905.

side of the charge, troublesome with large charges, negligible with small. Second, due to various irregularities in heat flow, less with narrow charges and small thermoelements, hardly ever over a degree or two. Third, due to conduction of heat down the thermoelement, also less with narrow charges and small thermoelements, for which it is usually negligible; but possibly amounting to several degrees with inclosed elements.

7. Electrical conductivity in the melt produces an error in the reading of bare thermoelements, thus far negligible in small charges of salts.

8. Contaminated elements, besides reading false, read so as to increase obliquity.

9. Differentiation and diathermancy of the charge probably increase obliquity.

10. Meltings have been made above 800° agreeing with each other to ·05°. In most cases an experimental obliquity remains of from ·5° to 1·5° (at high temperatures) whose cause is still to be definitely determined.

Geophysical Laboratory, Carnegie Institution of Washington,
Washington, D. C., July 15, 1909.

ART. XLV.—*Melting Point Methods at High Temperatures;* by WALTER P. WHITE.

IN an earlier paper of this series*, it has been shown that for melting-point determinations up to 1600° C. the platinum thermoelement, when used with a potentiometer (and with suitable precautions against the effects of contamination), is accurate, convenient, and rapid; the resistance-thermometer is inadequate in range, and ill adapted to the special conditions encountered; the direct reading pyrometer is seriously lacking in sensitiveness and accuracy and has very little advantage in convenience where portability is not essential. Furthermore, potentiometers and galvanometers now on the market are sufficient for the needs of the work, though special instruments can be devised which are both cheaper and more convenient. As low as 1000° most solid insulators show signs of an electrolytic conduction which increases with the temperature, while at about 1300° the air itself becomes conducting through ionization, but the disastrous effect which the relatively high voltage of the furnace current then produces on the delicate electrical temperature measurement can be completely avoided by protecting the measuring system with a metallic equipotential shield.

The present paper continues the discussion of apparatus and of the varying procedure necessary to determine melting curves according as the main object is the accurate location of heat absorptions, their quantitative measurement, or their mere detection when obscure.

PART I. *The Apparatus.*

I. *The furnace.*—The furnaces used in this laboratory are nearly always of the type described by Day and Allen five years ago.† For melting-point determination it has proved so satisfactory that further experience has suggested hardly any changes except variations in dimensions to suit different classes of work. Platinum wire of smaller size ($1\cdot2^{mm}$) has been found to answer, which cuts the cost nearly in half, but a specially pure platinum is now used in order to prevent contamination of the thermoelement by the iridium vapor which comes from the commercial metal. The furnace consists (1) of the coil, which is more effective the nearer it is to the

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* Potentiometer Installation, especially for High Temperature and Thermoelectric Work; Phys. Rev., xxv, 334, 1907.

† Temperature Measurements to 1600° C.; Phys. Rev., xix, 177, 1904.

working chamber, and is therefore wound on the inside of a cylindrical furnace tube;* (2) of the cylindrical tube which supports the coil, which must be refractory, a fairly good insulator of electricity at high temperatures, not apt to crack from heat, and of a material which can conveniently be plastered on and baked, in order to repair the defects which inevitably develop in use at the higher temperatures. Good thermal conductivity in this cylinder is not disadvantageous; indeed, it probably tends to prevent cracking from unequal distribution of the temperature. The dense mixture of magnesia and various other ingredients sold by the Harbison-Walker Company under the name of magnesite, which was in use five years ago, is still the best material we know for the purpose. (3) The outer layers of the furnace are merely heat-insulating material—a layer of an inch or more of calcined magnesia powder around the furnace tube and a very porous fire-clay outside of this and at the ends. The great porosity of the fire clay has several advantages; the clay is less likely to crack, it insulates heat better, and can easily be pierced with holes wherever desired for the insertion of thermoelements or other apparatus. These furnaces can be brought to red heat in less than 40 minutes by a current of 25 amperes, but will bear 40 amperes at the start. The working current at high temperatures is about 20 amperes (2000 watts). At 1600° a heating rate of 5° per minute has been safely employed, 7° at 1500°, and 12° or more at temperatures 100° lower. How much more than this the furnace can stand we do not know, and the attempt to find out would obviously prove rather expensive. The furnaces are heated by storage batteries, which furnish a practically constant voltage. The heating rate can easily be regulated so as to vary but 2 or 3 per cent from minute to minute, or a stationary temperature can be kept constant within a degree for hours with comparatively little attention. The real limit, however, to the effectiveness of the temperature control is the difficulty of securing uniformity of temperature throughout the working chamber.

The extreme softness of platinum at high temperatures and the tendency of the solid insulating and supporting materials to shrink and crack call for the greatest simplicity and strength in the form of construction, and practically compel the ordinary furnace to take the form of a vertical cylinder, heated only on the sides. The ends are always much colder and therefore any body within the central cavity inevitably suffers from an unequal temperature distribution, which is of course also

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*For the method of winding, see Arthur L. Day and J. K. Clement, this Journal, (4), xxvi, 411, 1908.

somewhat dependent on the body itself. Even in a horizontal direction, considerable differences of temperature occur. For instance, a difference of over 4° has been found between two points side by side *within* a small porcelain tube of only 8^{mm} internal diameter in a furnace held steady at 1000°. In this extreme case the tube was near the furnace wall, so that one side was shielded from the cooling effect of the ends. With the same tube in the center of the furnace the difference would not reach 1°, though horizontal differences of 2° or so, often variable from day to day, can hardly be prevented with large crucibles, even when symmetrically located. The vertical differences of course are greater. The furnace just mentioned was of our "general utility" type, with working chamber 6^{cm} wide and 14^{cm} high. In a furnace built specially for uniform temperature with a higher and narrower cavity ($4{\cdot}5 \times 23^{cm}$), fitted with four horizontal partitions to shield off the cooling effect of the ends, the temperature variation over a crucible 4^{cm} high was 20° at 500°, falling to 6° at 1500°. (Temperature differences inside the furnace usually decrease with increase of temperature above 500°.) A small porcelain tube (4^{cm} diameter $\times 10^{cm}$ long) in the center of the furnace chamber can be used to reduce irregular vertical and horizontal inequalities of temperature when the crucible is small enough to go inside it. The uniformity of temperature about the crucible is then sufficient for most melting-point determinations. For some other kinds of work, notably gas-thermometry, where greater uniformity is needed, other types of furnace have been developed. Considerable success has been obtained by the use of auxiliary coils* and with a combination of furnace and bath, but these are outside the field of the present paper.

For melting-point determinations with substances liable to be altered by oxygen, the air has been excluded by a glazed porcelain tube running through the furnace from top to bottom. With a tube 4^{cm} in inside diameter and $5{\cdot}0^{mm}$ thick, the melting of nickel (about 1453°) has been readily and satisfactorily observed.† The temperature distribution inside such a tube has not been studied. A platinum tube closed at one end has been used at various times to exclude air and also a closed porcelain cylinder.‡ The method of controlling the atmosphere about the charge by the use of an air-tight inclosure inside the furnace has, after trial of both, proved more effec-

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* Day and Clement, loc. cit., p. 412. See also, for a further account, a forthcoming paper in this Journal on the gas thermometer, by Arthur L. Day and R. B. Sosman.

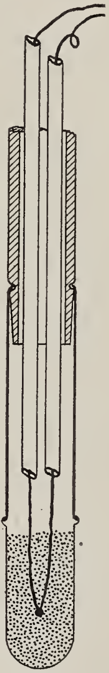
† Further details of this method will also appear in the forthcoming paper on the gas-thermometer.

‡ The Rôle of Water in Tremolite and Certain Other Minerals, E. T. Allen and J. K. Clement, this Journal, xxvi, 103, 1908.

tive and much more convenient than inclosing the whole furnace in an air-tight bomb.

II. *The crucibles.*—Two types of crucible installation have been used for inversion and melting-point determinations. The first is a relatively large crucible (5^{cm} in diameter) holding about 100 gr.[*] in which is inserted a porcelain tube for the reception of the thermoelement. (See fig. 2, previous paper, p. 455.) The porcelain tube is protected from the action of silicate melts by a platinum jacket. This passes through a platinum cover which shields the charge somewhat from the cooling effect of the furnace top. In case it is desired to stir or add to the charge when hot, the cover may be omitted, but it is much better to retain it even then and to add a second tube, opening into the crucible below through an appropriate hole in the cover. To prevent the platinum jacket from dropping off the porcelain tube when hot, notches are filed in the sides of the tube into which the edges of the jacket are bent. The jacket can afterward be twisted off easily by the application of a little force.

Fig. 1.



The second type of crucible (fig. 1) holds charges of about 1^{cc}. It is a platinum tube[†] borne on a porcelain tube open at both ends, to which it is fastened in the same manner as the platinum jacket described above. The thermoelement is passed down through and guided by the porcelain tube and its bare end dips directly in the charge. To insure proper centering of the junction in the charge (1) two capillary insulating tubes are used, one on each wire; these so nearly fill the larger tube as to be properly guided by it; (2) these tubes are brought as close to the junction as possible without danger of their touching the charge, thus leaving only 10 to 12^{mm} of the wire unsupported; (3) the two capillaries and the wires are firmly fastened together at the top, since a slipping of one wire up or down relatively to the other will bend the junction to one side; (4) the wires are pushed into the melted charge very

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[*] 25 gr. charges have also been used in the past, but do not afford sufficient depth of immersion for an inclosed element.

[†] For substances which can easily be removed by melting them out, the tube and crucible are preferably in one piece. For silicates, whose removal usually requires hard pounding, it is more economical of platinum to make the lower portion, which stands the wear, separate. When in use, it is held in place by crimping its edges over the slightly flared end of the upper portion (as illustrated in the figure).

slowly in order that the liquid may have time to yield, and not deform the metal, which has very little strength at high temperatures.

Each of these types of crucible has its advantages. With the larger, the thermoelements may be changed or compared during an observation, the melted charge may be prodded or sowed with crystals, or a sample may be taken, before heating, of the very mass of crystals whose melting-point is to be observed. With the smaller: (1) Melting points are much sharper, as pointed out in the preceding paper. (2) A far more uniform and steady distribution of the external temperature can be secured (by using shielding tubes around the crucible). (3) The expense for material, and especially for platinum, is far less—an important point with silicates, whose removal after cooling rapidly uses up crucibles. (4) The crucible and charge can be removed and replaced again without cooling the furnace. (5) By quickly inserting the charge in the furnace or raising or lowering it when there, it can be suddenly brought to almost any desired temperature of crystallization. In particular, by removing the melted charge and chilling it to glass, crystallization at some other temperature may then be secured with certainty.

In some early work on wollastonite* we considered ourselves fortunate when once a large crucible, cooled in the furnace, happened to cool below the inversion temperature before crystallizing and thus to give a cake of solid wollastonite. With the small crucibles this condition has since been repeated at will and rapidly.

Bare thermoelements dipping into crucibles of about 20 gr. capacity have also been used where the heat absorption was small and difficult of detection. Otherwise, their advantages will be sufficiently clear from the foregoing.

The special element described by Dr. Day† has, as far as its original purpose is concerned, been superseded by the small crucible with the bare element.

III. *The control element.*—Since the thermal behavior of a charge depends both on the charge and on the heat supplied to it, some knowledge of the source of heat is always necessary. To obtain it in delicate determinations, a "neutral body" has often been placed in the furnace with the charge, whose behavior is designed to show the effect produced by the furnace alone in the absence of the peculiarities presented by the charge. The control element as used in this laboratory differs from this device in giving, not the effect of the furnace temperature on a third body, but that temperature itself. The difference is

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* Allen, White and Wright, this Journal (4), xxi, 89, 1906.
† Day and Allen, loc. cit.

mainly a question of lag, but is often of considerable practical importance.

Where a single element is used the furnace is regulated for some time before the melting begins till a rate is assured which will carry it through. This takes time, and also requires judgment and experience, since the behavior of the furnace, when left to itself, will depend not only on its individual peculiarities just then, but on the conditions obtaining for a long while previous. With the control element, the observer is in command of his apparatus from first to last, and is relieved from much uncertainty as to its condition. Again, curves extending over long temperature ranges, with the single element, must be done in sections. The furnace rate keeps falling off, till it becomes necessary to stop, cool down a little, and then start again. This not only is tedious, but is a great disadvantage with substances whose condition depends on their previous history and is not wholly a function of their temperature at the instant. In one case we found a very important effect which would either have greatly confused our interpretations or would have been missed altogether if our curve had not been treated as a unit.

If meltings are carried on, as recommended in the preceding paper, with a constant temperature difference between furnace and charge, the control element is of course essential.

As actually used, the control element is merely inclosed in a porcelain tube—completely in ordinary cases, projecting (bare) beyond its open end where a specially close reading of the furnace temperature is wanted. Below about 1000° it can be arranged to be read singly, and also differentially in opposition to the charge element, so as to give directly the temperature difference of furnace and charge. At higher temperatures this differential reading, on account of the tendency to leakage, requires special arrangements which are ordinarily somewhat inconvenient. The difference is then best obtained by subtracting the separate readings, allowing, of course, for the change of furnace temperature which usually occurs between the taking of the two.

IV. *The thermoelements.*—Thermoelements of platin-rhodium are always used at high temperatures, on account of their superior constancy. For insulators to use with these, the Königliche Porzellan Manufactur makes tubes of so-called Marquardtmasse. This material, when unglazed, bends slowly if heated for some time in a horizontal position above 1500°, but when used vertically, as in an electric furnace, it is sufficiently refractory up to 1600°. It shows traces of conductivity as low as 1200°, but in our comparisons of thermoelements at various temperatures no error due to this conductivity has ever been detected. The tubes used in our furnaces are of two kinds, first an outer protecting jacket 8^{mm} internal, 10^{mm} external diameter, and closed below, separating the element from the charge. These tubes also make a convenient support for small crucibles, as already described. When so used, they can be many times inserted in and withdrawn from a hot furnace without cracking, and their life is almost indefinite when not subjected to this severe treatment. When glazed, they are much less durable, cracking rather easily, and cannot be used with tight-fitting platinum jackets, but have the important advantage of shielding the thermoelements from the iridium vapor of the furnace. The other tube is an unglazed open capillary of 2^{mm} outside diameter, for insulating the wires of the thermoelement from each other. Ordinarily, one wire of the thermoelement is left bare. This is necessary in comparing elements, and more convenient in most other cases, except with the small crucibles, as explained above (p. 477).

Recently, capillary tubes of "quartz glass" have been put on the market, which are cheaper than the porcelain and impervious to most gases. Where a curved tube is needed, they are indispensable, for they can be bent (in the oxyhydrogen flame) more easily than ordinary glass tubing. Above about 950° they cease to be permanent, slowly devitrify (crystallize), and become brittle, but can still be used where their special advantages justify the trouble and expense of frequent renewals when necessary.

To diminish the difficulties arising from contamination of the thermoelements:* (1) Commercial platinum, with its high content of iridium, must be banished from the furnace altogether. (2) The elements used for the final measurements are exposed to the high temperatures for the shortest time possible. (3) They are also compared frequently with standards. (4) Great care is taken in standardizing to use the same type of furnace and the same depth of immersion (almost to a millimeter) as for the temperature measurement. (5) The elements are cut off from time to time to remove the worst contaminated portion. Of prime importance in this connection is the fact† that the reading of a thermoelement depends mainly on the parts of it which lie in the steeper temperature gradients. The pains taken to preserve constant depth of immersion are for the sake of keeping the same portions of wire exposed to the same temperature gradient. In our furnaces a difference in depth of immersion of one centimeter may alter the *error* of a contaminated thermoelement from 20 to 30 per cent. Where contamination has gone too far, it is

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* Constancy of Thermoelements, W. P. White. Phys. Rev., xxiii, 463, 1906. Reprinted with important additions, Phys. Zeitschr., viii, 332, 1907.

† Phys. Rev., xxvi, 535, 1908.

sufficient to cut off 2 or 3^{cm}, merely enough to bring fresh wire down into the gradient region, which lies near the top of the furnace. The time to do this is evidently when the contamination has become so great that the correction for it has more than the allowable uncertainty. Practically, a lowering of one degree in the reading is about the limit allowed in most of the work of this laboratory.

The gas-thermometer scale is transferred to the thermoelement by means of metal melting-points, which are therefore the practical temperature standards in our work. A thorough treatment of this question will accompany the forthcoming paper on the gas-thermometer. Here it is sufficient to say that it is useless to calibrate contaminated elements directly by the metal melting-point method, since the introduction of a large crucible of metal into our furnaces seriously alters the temperature gradients which previously prevailed. Extrapolation is then particularly treacherous. But with wires of the homogeneity now attained in the Heraeus elements an element may be relied upon to return to its original reading when properly amputated. It is hardly necessary to say that the average of several calibrations is more to be relied upon than a single one, and this means that in case an element has been calibrated several times with concordant results, and is then cut off to remove contamination, for the new element thus formed the average of the preceding calibrations is more to be relied upon than a single new one. The same is true of a calibration established by comparison of one element with another whose calibration is known to be good. The opportunity for error in the comparison, if properly conducted, is less than that in a curve from a single set of melting-points made with equal care.

The calibration of contaminated elements, which requires a particular temperature gradient, can be performed either with charges of silicates or other salts, which will go in almost any furnace, or by direct comparison with standards. The standards can also be used to calibrate new and perfect elements. Such comparisons are also far less laborious than melting-point determinations.

For very high accuracy in direct comparison it is absolutely necessary that the two junctions be at the same temperature. This is secured at high temperatures, either by thrusting the two elements, without electrical contact, side by side into one of the 8^{mm} porcelain tubes and maintaining a uniform horizontal temperature distribution around this tube (by a bath of silver, a block of iron, or simply by putting the tube carefully in the center of the furnace and surrounding it with a ballast tube 4^{cm} in diameter); or the two elements are first inserted and read, then removed, transposed and inserted again, so that each is on the side of the tube opposite to that occupied before; or the whole tube, with the elements in it, is turned around.

To keep the standards constant, intercomparisons are usually made at no higher temperature than 1000°. The variation measured at this temperature, if not over a degree, gives a sufficient indication of the value higher up.

Part II. *Particular Methods.*

I. *Simple melting points.*—To obtain these, it is necessary, after the furnace, crucible, and thermoelement are properly arranged, to read the temperature of the charge at successive intervals (one minute is usually often enough, though not always) for from 5 to 15 minutes during the critical upper portion of the melting curve, and at the same time to insure a fairly regular rate of change in the furnace temperature. To do this the experimenter must (1) read (and record) the element in the charge; (2) read the furnace control element beside the charge; (3) keep his galvanometer in correct zero adjustment; and (4) regulate the furnace if the thermoelement readings show a need for it. For this purpose he may first determine the furnace rate each minute by subtracting the control element reading from that for the previous minute.* The difference will in general diminish steadily if the furnace is left to itself. It can be kept constant and greater accuracy secured (pp. 461, 479, and 485) by regularly cutting out resistance from the circuit of the heating current.

If a constant flow of heat into the crucible is desired, there is usually a little imperfection in the furnace regulation near the beginning of melting, when the progress of the furnace temperature must be strongly checked. When the final melting temperature is reached the furnace is nearly stationary and the regulation therefore particularly easy and satisfactory.

It is desirable for several reasons to watch the charge rate also by subtracting the successive readings from each other. The two subtractions and the furnace regulation can easily be accomplished within a minute with good galvanometer arrangements, and still leave the experimenter with the extra time necessary to insure against oversights in switch setting or arithmetical work. It is a little better if the two readings come close together, so that the observer's spare time during each minute also comes all together. Readings can easily be made within 10 seconds of each other. To this end, however, it is highly desirable that all intervals smaller than 100 mv. be

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* Unless a direct differential reading is provided for, as described on p. 479 and illustrated on p. 484.

read as galvanometer deflections.* At the end of a determination the adjustment of the potentiometer storage battery is verified by means of the standard cell, and the effect of electrolytic leakage, if any, in the furnace is tested by breaking, or better, suddenly reversing, the heating current.

Table I gives a typical notebook page for a melting-point determination. All but the italicized portions belong to the original record, made during the observations. Here the furnace was first regulated for constant rate by the control element alone, and then when the temperature difference corresponding to that rate had been found, it alone was used for the rest of the observations.

II. *Melting points of viscous substances.*—If the melting shows much hysteresis (preceding paper, page 456), the thermal method fails entirely. This difficulty, however, contains its own remedy, for the viscous substance can at any time be removed from the furnace near the expected melting point and chilled† so as to fix the exact stage of melting then reached. The portions already melted solidify to glass which is permanent at room temperature. (With extremely viscous substances, even the chilling is not necessary, as recrystallization takes place very slowly at any temperature.) This gives a sort of "successive approximation" method of determining the melting point. It excels the old methods of watching the substances in the furnace for signs of melting, in two respects; (1) it is better thermally, since the furnace can be larger and more completely closed, hence temperatures are more easily kept both constant and uniform ; (2) it is better optically, since the substance is examined at room temperature.

III. *Quasi-calorimetric determinations.*—It has been pointed out in the previous paper that a melting-point determination involves some knowledge of heat supply as well as of temperature. It is thus essentially a calorimetric determination and may easily be so conducted as to bear a calorimetric interpretation, of greater or less accuracy. This may be a determination of the entire melting curve, discussed in the previous paper, or simply of the latent heat of a single change of state. Hüttner and Tammann‡ have given examples of the latter, using a falling temperature, i.e., freezing instead of melting curves. They take the heat loss as simply proportional to the time, and propose the method as a rapid but only an approximate one. Plato§ finds, by using a somewhat different procedure, that the heat loss may be taken proportional to

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* Compare Potentiometer Installation, etc., Phys. Rev., xxv, 339, 1907.

† A. L. Day and E. T. Allen, this Journal (4), xix, 120, 1905.

‡ Zeitschr. f anorg. Chem., xliii, 215, 1905.

§ Zeitschr. f. phys. Chem., lv, 721, 1906.

TABLE I.—TYPICAL ORIGINAL RECORD OF A MELTING POINT DETERMINATION.

June 17, 1909.		Na_2SO_4 + 1/3%NaCl. Charge 9 × 48mm.		Element immersed 27mm.
Control	$\frac{\delta\theta}{\delta T}$	Charge	$\frac{\delta\theta}{\delta T}$	Differential Reading. *Control—Charge*
7329				
	54			
7383				
	50			
7433				251
	57			
7490		7281		225
	58		77	
7548		7358		205
	52		68	
7600		7426		189
	50		61	
7650		7487		179
	51		58	
7701		545		174
			57	
		602		170
			56	
		658		165
			55	
		713		160
			51	
		764		153
			50	
		814		151
			47	
		861		148
			47	
		908		152
			48	
		956		152
			46	
		8002		152
			41	
		043		158
			36	
		079		156
			26	
		105		157
			22	
		127		155
			15	

June 17, 1909.		Na_2SO_4 + 1/3%NaCl. Continued.		
Control	$\frac{\delta\theta}{\delta T}$	Charge	$\frac{\delta\theta}{\delta T}$	Differential Reading. *Control—Charge*
		8142		156
			13	
		155		153
			10	
		165		158
			8	
		173		155
			6	
		179		154
			7	
		186		156
			5	
		191		157
			5	
		196		155
			4	
		200		155
			3	
		203		156
			4	
		207		153
			3	
		210		148
			2	
		212		150
			2	
		8214		156
			3	
		217		158
			16	
		233		144
			44	
		277		121
			45	
		322		140
			60	
		383		150
			64	
		446		148

Cadmium Cell balance O K

Each line of readings corresponds to one minute. The furnace was regulated each minute when necessary. Readings in microvolts: 1MV=0·09°.

the square of the time after freezing begins, and claims very high accuracy. This method also involves some approximations and restrictions which, while not incompatible with excellent agreement of the results, seem rather unnecessary, since they can readily be avoided simply by a direct measurement of the furnace temperature. Such a measurement is very easily made; it gives at once and without any uncertainty the temperature difference on which the heat supply to the charge depends, and leaves the observer a wider choice of methods in controlling his furnace. Its results are also of easier interpretation than with the "neutral body," whose temperature, though a function of that of the furnace, is related to it in a complicated way. In fact, no one seems to have attempted to determine heat absorption quantitatively by aid of the neutral body.*

The use of a single control element, though an improvement, gives little more than a first approximation. The heat supply to the charge is equal to GKT where G is the external temperature gradient, that is, the temperature difference of charge and furnace, K is a heat-flow factor (conventionally called a radiation factor), and T is the time. K varies with the absolute temperature and this variation can be determined if a body of known specific heat at different temperatures is available, or it may often be negligible.† K also varies greatly with G, but this variation is hard to determine, since the large values of G which may occur during a melting often can not be obtained at any other time.‡ The remedy for this difficulty is to keep G constant throughout; this has the further great advantage of eliminating the effect of systematic errors in G, which can hardly be avoided. This procedure, however, since it changes the furnace rate, tends to aggravate another source of error, the variation in temperature distribution in the furnace, as a result of which the control-element reading bears a different relation to the mean effective furnace temperature at different times. Attempts to avoid, by special apparatus and procedure, this source of error have shown it to be very serious at high temperatures, but have not as yet indicated clearly the most effective means of diminishing it. Another source of error lies in the differences of temperature within the charge, and especially the difference between the thermoelement, in the center, and the outside surface, from which the loss of heat

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* See footnote, p. 460, previous article.

† All the sources of error here treated have been hitherto disregarded in work at high temperatures, though the least of them may at times cause an error of 5 per cent of the heat quantity measured.

‡ Plato, though he does not appear to recognize this difficulty, does in fact avoid it by making what corresponds to a determination of K during the violent temperature drop which immediately follows the freezing. But this method seems open to grave objections, in spite of its excellent results in his case.

actually occurs. This error is diminished, as shown in the preceding article,* by reducing the diameter of the charge.†

All these effects conspire to make "radiation" calorimetry somewhat analogous to some of the rapid volumetric methods of analytical chemistry. Under strictly constant conditions results can be reproduced with great uniformity, but their actual accuracy is dependent, first, on a calibration by some absolute method, and then on the subsequent absence of variation in numerous details, the importance of some of which may easily be overlooked. The absolute method thus far available in calorimetry at high temperatures is the method of mixtures, where the body under investigation is dropped from the furnace into a calorimeter.‡ Where that can be used, the radiation method will probably depend on rapidity or convenience for its usefulness, but hardly seems likely to furnish the final, most accurate values.

With most silicates, however, the dropping method cannot be used, since their inversions and changes of state will not occur normally with a rapidly falling temperature, and often not even with a very slow fall. This makes the radiation method more necessary, but at the same time deprives it of independent calibration in the very region where that is most needed, i.e., at the high temperatures where most silicates melt. The rapid increase of K and consequent tendency toward smaller values of G with rising temperature greatly increase the disturbing effect of small variations in temperature distribution. A calorimetric problem of some difficulty is thus presented, whose consideration does not belong here. It has only seemed desirable to call attention to the present limitations, as well as the possibilities, of such quasi-calorimetric determinations as can be made with simple melting-point apparatus.

As an illustration of these: numerous determinations, with 2·5 gram charges, of the latent heat of various silicates melting above 1300° agreed to 3 per cent, but the systematic error may be 15 per cent, so that it has not seemed desirable to publish the results.§

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* Pages 462, 466. The difference between center and outside is not only smaller, but relatively more constant (p. 464) in the small charge. Its effect almost disappears where G is kept constant.

† Still greater accuracy has been obtained by making the crucible wall itself the junction, and then measuring the temperature difference differentially. Results are then consistent at least to 0·5 microvolt, or about ·03°, above 1400°.

‡ Plato, loc. cit. Goodwin and Kalmus, Phys. Rev., xxviii, 1, 1909. J. A. Harker, Phil. Mag., x, 430, 1905, 1906. W. P. White, this Journal, xxviii, 334, 1909. A full set of references in this subject might be hard to make, and does not seem needed here.

§ If, however, the order of magnitude is of interest, it may be taken as 106 ± 15 calories for diopside, about 350 times (numerically) the specific heat of the solid just before melting.

When the latent heat is small, as in most inversions, the variations in the values of G, in the furnace rate, etc., are also small, and the radiation method is easily made fairly accurate. Two determinations of the inversion heat of wollastonite, made with the simple 2·5 gram charge, agreed to 0·3 calories, and a very generous estimate of the possibilities of systematic error does not allow more than 1·5 calories.*

The experimental arrangement for quasi-calorimetric determinations usually does not differ in any respect from that for simple melting points at constant values of G. The determination illustrated on p. 484 was, in fact, quasi-calorimetric. For the greatest accuracy the equipotential leakage shield (p. 474) should be as complete as possible, and should be on the inclosing 4^{cm} tube, instead of connected to the crucible itself.† The heat supplied to the charge within any interval is determined simply by adding the values of G‡ for that interval; since each value of G corresponds to one minute, this gives at once the value of TG. A correction for the observed variation in K may also be needed. The other steps in the calculation do not seem to call for special description.

IV. *Small thermal effects.*—Some thermal effects, especially inversions in the solid state, are so slight that their mere detection is a problem in itself. Determinations of this character, like the preceding, depend on accurate heat measurement, though here the behavior of the charge is no longer a complication. The difficulty is rather to secure, in the furnace itself, conditions so uniform and reproducible that very slight variations occurring within the charge may be recognized at once. This requires, of course, chiefly precision in temperature measurement and regulation. It is also promoted by increasing the size of the charge, thus increasing the temperature difference, furnace to crucible, and diminishing the effect of small temperature irregularities.

The feeble intensity of these thermal effects is usually due as much to the slowness of the heat absorption or evolution as to its small magnitude. Hence a rapid furnace rate, which concentrates the effect, greatly aids in its detection. The wollastonite inversion, for example, with a rate of 10° per minute, can be accomplished in about 10 minutes with an uncertainty of less than 1·5 calories (2·5 gram charge). Under like conditions two calories should therefore be capable of detection.

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[*] The result was 10·0 ± 1·5 calories.

[†] The more elaborate arrangements referred to in the footnote to page 486 are not properly within the scope of this paper.

[‡] Really, the values of the temperature difference between center of charge and furnace, which is greater than G by the amount of the gradient in the charge, but proportional to it.

It is in determinations of this sort that the neutral body is particularly advantageous,

If the inversion takes place promptly at a constant temperature (as for instance, with the quartz inversion at 575°) its detection is evidently much easier. For the best results a temperature reading should come immediately after the inversion occurs, and before its effect has been dissipated by temperature exchange with the furnace. The interval between readings should be as short as possible with a rate about fast enough to supply all the latent heat in one interval. A rather small fraction of a calorie could probably be detected in this way.

Allen, Wright, and Clement* confronted this problem of detecting small energy changes in their study of the inversions of $MgSiO_3$ and finding the Frankenheim method inadequate they developed a new one, whose essential feature was the production of a very rapid rise of temperature in the substance under examination by dropping it into a previously heated furnace. The method here described is still the Frankenheim method but with some improvements due to accumulated experience. It is now several times as sensitive as is necessary to detect one of the $MgSiO_3$ inversions.

V. *Residual meltings.*—The eutectic melting produced in diopside by 2 per cent of pseudowollastonite is easily measurable on the smooth curve which precedes the melting point. At the end of melting, however, as the last portions of solid core or crust disappear in liquid, the temperature distribution and variation in the crucible is irregular, and a rapid temperature rise occurs. Hence, in the common case of eutectic mixtures containing a very small excess of one component, its detection may be impossible on an ordinary melting-point curve. The accurate location of the eutectic, however, requires the detection of these small residues as the composition of the melt is varied in the adjacent region. For this purpose two like crucibles may be placed symmetrically within the inner tube, containing either two mixtures of slightly different composition whose relative nearness to the eutectic we wish to determine, or two substances one of which is supposed to contain and the other known not to contain the small residual whose melting is being investigated. The temperature of these is slowly and carefully raised until the (previously measured) main melting point is just passed, an operation requiring a little patience, but presenting no particular difficulty. The furnace will then be stationary. The temperatures are read, the heating current of the furnace is suddenly increased and alternate readings of the two crucibles made every 15 seconds as long as necessary. After the suspected region has been traversed, the furnace is brought to a (higher) constant

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* This Journal, xxii, 415, 1906.

temperature, and the operation is repeated as a control experiment to see if there is anything in the situation of the crucibles or the peculiarities of the thermoelements calculated to imitate the thermal behavior produced by the presence of a residual in one more than the other. An example of such a determination is given in a previous paper.* The magnitude of the result there obtained with a 2 per cent excess of $MgSiO_3$ indicates that at least ·25 per cent could probably be recognized.

Summary.

1. Platinum resistance furnaces of simple construction provide complete control of the temperature for melting-point work up to 1600° C. Where uniformity of temperature throughout the working-chamber is important special modifications are necessary.
2. Small charges (2·5 grams) give very sharp melting points, are economical of material, and permit of convenient manipulation.
3. A number of advantages result from the use of a second thermoelement, which is made to give directly the furnace temperature about the charge. The measurement and regulation of the heat supply from the furnace is a factor of great importance in accurate melting-point determination.
4. Methods of treating and insulating thermoelements and of avoiding the effects of contamination have been developed, suited to various conditions and kinds of work.
5. The melting points of very viscous substances, showing hysteresis, can be determined easily and effectively by very slow heating, and occasional examination outside the furnace.
6. The approximate determination of latent heats of fusion directly from melting curves is possible by measurement of the furnace temperature, but is encumbered by several hitherto undetermined sources of error. The attainment of an accuracy greater than 10 per cent (about 10 calories in many silicates) accordingly requires special apparatus and procedure. The smaller latent heats of inversion can usually be determined to one or two calories with no other apparatus than the two thermoelements.
7. For determining faint or sluggish thermal effects, rapid rates of heating and the utmost precision in furnace regulation and temperature measurement are needed.
8. The accurate location of eutectics by thermal means requires the detection of small residues of the component in excess. This can be accomplished by a special method involving the use of a neutral body.

Geophysical Laboratory, Carnegie Institution of Washington.
Washington, D. C., July, 1909.

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* Diopside and its Relations to Calcium and Magnesium Metasilicates, this Journal (4), xxvii, 11, 1909.

Art. XLVI.—*On the Existence of Teeth and of a Lantern in the Genus Echinonëus* Van Phels; by Alexander Agassiz. (With Plate II.)

While making some preparations of the teeth of Echinonëus for a report I am preparing on the specimens of the genus collected by the "Albatross" in the tropical Pacific, Mr. Magnus Westergren made the interesting discovery of the presence of teeth and of a fully developed lantern (Plate II, figs. 1, 3) in young specimens of the West Indian species of the genus *E. semilunaris* Lam. These young specimens (Plate II, figs. 1, 2), measuring only 3·70^{mm} and 4·25^{mm} in length, were collected at Port San Antonio, Jamaica, by Professor Hubert L. Clark. This is perhaps one of the most interesting recent discoveries in the domain of echinology, considering the relationship hitherto recognized of Echinonëus to the Atelostomata. The presence of teeth would transfer them to the vicinity of such types of the exocycla Gnathostomata as Holectypus, Discoidea, Pygaster (Echinoconidæ) and more remotely to the Conoclypidæ.

The demonstration of this interesting relationship would be interesting in itself, but its great importance lies in the fact of the disappearance of the masticatory apparatus at a very early age. Young specimens of Echinonëus measuring 5·1^{mm} in length, and but slightly larger than those in which teeth were observed, have no teeth or lantern (Plate II, fig. 10) and nothing is left of them but the presence of small auricles (Plate II, fig. 4), so that in the older and adult stages of Echinonëus its relationship to the Spatangoids is in no way modified.

The figures given on Plate II are sufficient to illustrate the novel points in the structure of Echinonëus. A more detailed description will be given in a subsequent report on the genus. Fig. 1, a profile figure of a young Echinonëus measuring 4·25^{mm} in length, shows the position of the lantern with its compass and teeth as well as the course of the œsophagus and of the wide folds of the alimentary canal (i' and i'') terminating in the intestine leading to the anal system; *ia* is a peculiar bag-shape apparatus attached to the upper fold of the alimentary canal, which is held in place by a line of mesenteries attached to the test.

Fig. 2, a transverse section of the test of a young specimen of about the size of fig. 1, 3·70^{mm} in length, shows the actinal floor of the test from above, with the anal system (*an*) and the lantern in place, as well as the pyramid (*py*), the compass, *c*, and the pentagonal muscular band of the upper part of the lantern (*pm*).

Fig. 10 is a profile view of a young specimen 5·16^{mm} in length, in which the jaws, lantern and pyramid have disappeared; the lettering of the parts is as in fig. 1.

Fig. 3 shows the lantern more in detail; it is 1·3^{mm} in diameter; *oes* is the opening of the œsophagus leading into the lantern; *pm*, the horizontal muscular band of the lantern; *c*, the compass; *py*, the pyramid; *a*, *a*, *a*, *a*, the small auricles; *mc*, the muscular band of the compass; *l*, the labium.

Fig. 4 shows the position and shape of the auricles, *a*, of a specimen 4·10^{mm} in length.

Fig. 5 shows the pyramid with the tooth (*t*) seen from the grooved side, while fig. 6 is the same showing the tooth from the keeled side. The pyramids are solid without foramina. The shape of the compass is shown in figs. 8 and 9, the profile and dorsal views of the same.

The appearance of the young Echinonëus after the disappearance of the lantern is shown in a profile view of the same, fig. 10. How this disappearance takes place I am unable to state, the material at my command showing no intermediate stage between that of fig. 1 and of fig. 10. It is possible that the lantern disappears by resorption; the whole of the calcareous deposits in the masticatory apparatus is most loose and delicate. Its resorption would be in harmony with the resorption of many parts in the test and spines of other Echini.

It is interesting to note that this dentate stage of Echinonëus should connect the embryonic Spatangoids with the early stages of Clypeastroids and of the Echinoconidæ, while the toothed Pygastroides of Lovén connects it with some of the Echinoconidæ; both Echinonëus and Pygastroides are West Indian genera.

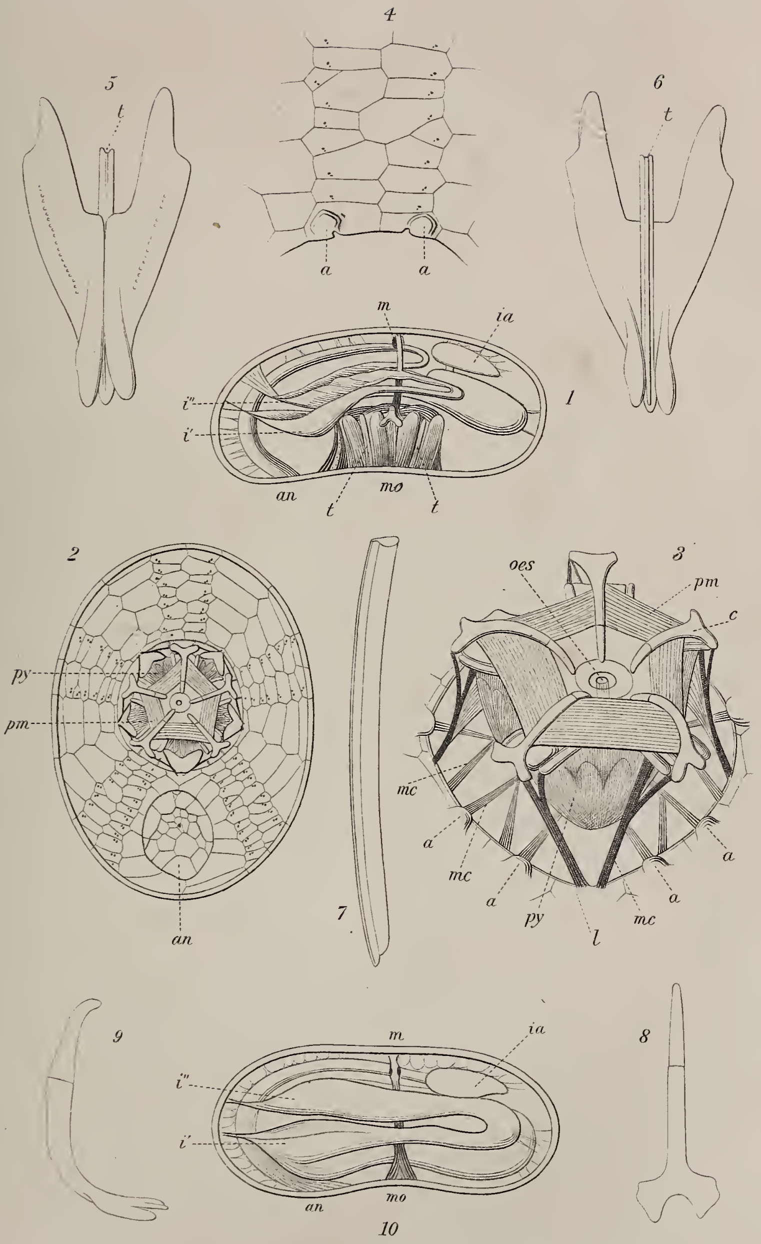
The presence or absence of auricles, teeth and pyramids forms the basis of Zittel's classification of the irregular Echini into Gnathostomata and Atelostomata. The position of the anal system on the actinal surface close to the actinostome is a very modern feature: its gradual passage from an anal system enclosed within the calycinal system as in Pygaster, where it is outside of the abactinal system, can be traced towards the ambitus to the ambitus and finally to an actinal position.

In some of the Holectypidæ the jaws are greatly reduced in size and solidity and their importance much lessened, and in others the jaws have entirely disappeared, the perignathic girdle having become rudimentary. In the Echinometradæ the auricular girdle is most highly developed. In the Holectypidæ we find primitive irregular Echini as well as types which have persisted to the present day. In the Discoidea and Galerites the ambulacral processes and teeth are absent; in the auricular girdle the processes become low. In the Clypeastroids there are neither braces nor compass, the jaws move horizontally, and finally in the Atelostomata the girdle and jaws are completely absent. We may imagine the process of resorption of the lantern of Echinonëus to have gone through some such succession.

EXPLANATION OF PLATE II.

a, auricle ; *an*, anal system ; *c*, compass.
i′, actinal loop of the alimentary canal.
i″, abactinal loop of the alimentary canal.
ia, abactinal intestinal appendage.
l, labium.
m, madreporic tube.
mc, muscular band leading to compass.
mo, actinostome.
pm, pentagonal muscular band of summit of lantern.
py, pyramid.
t, tooth.

1. Profile longitudinal section of young Echinonëus measuring $4{\cdot}25^{\mathrm{mm}}$ in length.
2. Transverse section of young, $3{\cdot}70^{\mathrm{mm}}$ in length and $2{\cdot}55^{\mathrm{mm}}$ in width, showing the actinal floor, the position of the lantern, and of the actinostome seen from the abactinal side.
3. Lantern of Echinonëus magnified ($1{\cdot}30^{\mathrm{mm}}$ in diam.) same as fig. 2.
4. Actinal part of ambulacral system seen from the interior of young $4{\cdot}19^{\mathrm{mm}}$ in length to show the auricles.
5. Pyramid and tooth seen from the exterior, length $0{\cdot}85^{\mathrm{mm}}$.
6. Pyramid and tooth seen from the interior, length $0{\cdot}85^{\mathrm{mm}}$.
7. Tooth seen in profile, length $0{\cdot}62^{\mathrm{mm}}$.
8. Compass seen from above, length $0{\cdot}62^{\mathrm{mm}}$.
9. Compass seen in profile, length $0{\cdot}62^{\mathrm{mm}}$.
10. Profile of young specimen measuring $5{\cdot}16^{\mathrm{mm}}$ in length ; the lantern and auricles have disappeared.



A.M. Westergren del. B. Meisel lith.

THE GENUS ECHINONEUS.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Separation of Titanium, Niobium and Tantalum.*—The quantitative separation of these three acid-forming elements has been regarded as one of the most difficult problems of analytical chemistry. LUDWIG WEISS and MAX LANDECKER of the University of Munich have now made an elaborate study of the matter, and they appear to have made a great advance in the solution of this problem by the use of unexpectedly simple operations. An outline of their method for the analysis of columbite and tantalite is as follows: The usual fusion is made with acid potassium sulphate, the resulting mass, after cooling, is extracted with hot water containing sulphuric acid, and to the boiling solution sulphurous acid is added in moderate amount (20 or 30^{cc}) until the precipitate loses its milky appearance and becomes flocculent. After boiling for 20 or 30 minutes the precipitate, which contains the tin and the rare acids, is filtered and washed with a hot solution of sulphuric and sulphurous acids. It is advisable to pass hydrogen sulphide through the filtrate and to collect any tin that may have remained in solution. This filtrate is then to be analyzed for the metals by the usual methods. The precipitate of acids is now treated thoroughly, as usual, with hot, yellow ammonium sulphide for the extraction of tin. The residue is ignited and fused in a platinum crucible with sodium carbonate and with the addition, shortly before the end of the fusion over the blast lamp, of a little sodium nitrate in such a way (igniting only for 8 or 10 seconds) that some of the latter remains undecomposed. The amount of sodium carbonate should be only about double that of the mixed acids, and the sodium nitrate should be used sparingly. The mass is then extracted with boiling water for some time in order to dissolve all the tantalate, the insoluble titanium residue is filtered off, and a few drops of the filtrate are tested with hydrogen peroxide for titanium. If this is present, as is the case only when more than from 3 to 5 per cent of titanium is present, hydrogen sulphide gas is passed into the cold liquid, producing a grayish-white precipitate containing all the titanic acid present here, and thus separating it from niobium and tantalum. This precipitate is washed with sodium sulphide. If titanium is not present, carbon dioxide is led into the liquid in order to precipitate tantalum and separate it from niobium, but when hydrogen sulphide has been used it is necessary to destroy the sodium sulphide with sulphuric acid, to precipitate the acids with ammonia, and to make another fusion with sodium carbonate and nitrate in order to obtain a solution suitable for the precipitation of tantalic acid. This operation is performed by passing the carbon dioxide for a long time in the cold. The

precipitate begins to appear after 50 minutes. Then after passing the gas for half an hour longer, when the precipitation is usually finished, the liquid is boiled for a short time, and the precipitate is allowed to settle over night before filtering. The authors have obtained very satisfactory results with these separations, but much seems to depend upon the proper conditions in making the fusion with sodium carbonate and nitrate. The original article should be consulted in regard to further details..—*Zeitschr. anorgan. Chem.*, lxiv, 65. H. L. W.

2. *Electrical Discharges from Radium Emanation.*—In connection with work on the collection of the emanation from about 0·2 g. of radium, Debierne has observed spontaneous electric discharges visible in daylight, in the little tubes containing the emanation at atmospheric pressure. The sparks are often as frequent as once a minute, and are sometimes several millimeters in length. They are usually produced in the interior of the glass of the capillary tube, which is then furrowed with little cracks resulting from their passage. The sparks often start from a very brilliant point on the surface of the tube in contrast with the emanation. Sometimes the electric discharge is produced across the emanation itself, which is rather brightly illuminated. These discharges are only produced with certain kinds of glass. A glass which showed them most often was one containing lead, which became violet under the action of the emanation, but glass containing a large proportion of lead did not show the phenomenon. The discharges may be attributed to the accumulation in the glass of the electric charges of the α and β rays when the glass is a sufficiently good insulator.—*Comptes Rendus*, cxlviii, 1264.

H. L. W.

3. *Outlines of Chemistry*, by Louis Kahlenberg; 8vo, pp. xix, 548. New York, 1909 (The Macmillan Company).—This is a text-book designed for the use of college students. It is intended to represent one year's work in connection with experimental lectures and laboratory exercises, but no directions for experiments are included in it. It is a rather large book containing a comparatively large amount of descriptive matter. The theoretical discussions are distributed through the book in connection with the appropriate facts. Quite a little attention is paid to historical matters, and the most important technical applications have been emphasized. In general the work seems to be an excellent one, and sufficiently different from the large number of books of nearly the same scope to be well worthy of existence. Some fault may be found with certain statements in regard to iron and steel, but metallurgical weakness is characteristic of nearly all of our text-books of general chemistry. The author's attitude towards the ion theory of Arrhenius is a surprising one for the present day, for he rejects the theory as untenable, although he gives a fairly extensive discussion of it. Perhaps this attitude towards the ionic hypothesis may be considered preferable to its too enthusiastic use in a text-book of this kind. H. L. W.

4. *The Fundamental Principles of Chemistry*, by WILHELM OSTWALD: Authorized Translation by HARRY W. MORSE; 8vo, pp. xii, 349. New York, 1909 (Longmans, Green & Company).—"An introduction to all text-books of chemistry" is the sub-title given to this book by its distinguished author. This does not mean, however, that it is suitable for the use of beginners who have no knowledge of the science. It is an essentially non-mathematical discussion of chemical principles from physical and philosophical standpoints, which will be of interest to more advanced students and teachers. The well-known attitude of the author in discarding the atomic and molecular theories gives a somewhat peculiar aspect to his theoretical considerations. He uses "combining weight" in the place of atomic weight, and his "molar weight" in the place of molecular weight appears to be a mere makeshift. From this point of view his treatment of such topics as valence and ions is curious, to say the least. The translation appears to be exceedingly well done. H. L. W.

5. *Elementary Modern Chemistry*, by WILHELM OSTWALD and HARRY W. MORSE; 12mo, pp. 291. Boston, 1909 (Ginn & Company). This small text-book is the result of the collaboration of the distinguished German chemist and an instructor in physics in Harvard University. It gives an interesting series of physical and chemical experiments, a moderate amount of descriptive matter, and a good proportion of theory. Owing to Ostwald's peculiar views, the atomic weights connected with the list of the elements are called "combining weights." It may be observed that this term does not apply as yet to argon, helium, etc. It is also to be noticed that Avogadro and his theory do not appear to be mentioned in the book. The illustrations are good, including full-page portraits of Priestley, Ramsay, Dalton, Faraday, Berthollet, Bunsen, Gibbs and Berzelius. Plaster-of-paris is characterized as an anhydrous compound. The statement about wrought iron "containing usually less than 1 per cent of carbon" is misleading, and the view that suddenly cooled cast iron makes "white iron or spiegel" is remarkable. These are small defects, and the book on the whole has many excellent features. H. L. W.

6. *On the Resistance due to Obliquely Moving Waves and its dependence upon the particular form of the forepart of a ship.*—LORD RAYLEIGH refers to the train of waves which leave the bow of a ship. These waves have been studied by the Froudes and an analysis of them is given in Lamb's Hydrodynamics (3d ed. p. 414). More attention has been directed to the directly advancing waves, those whose crests are perpendicular to the ship's motion, than to the effect of the oblique part of the wave system. Lord Rayleigh has made experiments upon a new form of bow and stern which might neutralize the holding-back effect of the additional pressure due to the crests of the train of waves, and he suggests that larger experiments should be made, with what may be called an undulating figure of bow and stern, instead of the present convexity of these portions of a ship.—*Phil. Mag.*, Sept. 1909, pp. 414–416. J. T.

7. *Excitement of Positive Rays by Ultra-violet Light.*—The origin of positive rays is still undecided. Riecke and Ewers attribute them to positively charged metal ions shot off from the cathode metal. Gehrcke believes that they are due to the light electric effect of the electric discharge on particles shot out from the cathode. This higher electric effect results in a redistribution of electrons, and the formation of positively charged particles. W. Wien believes that a regeneration can take place in a jar after an electric discharge has passed through it and after the discharge has been submitted to the effect of a magnetic field. H. Dember has made an investigation of the production of positive rays by means of ultra-violet light. By means of the Wehnelt electrodes and the rays of a quartz quicksilver lamp, he was able to excite the rays by a small difference in potential. The experiments were carried out over a large range of pressures. The lowest pressure was obtained by means of Dewar's method of charcoal and liquid air, and extended from $0{\cdot}000011^{mm}$ to $0{\cdot}000008^{mm}$ of mercury. The curves obtained in the extreme vacuum show that what may be termed jostling ionization does not appear, and therefore the observed positive particles arise from something shot off from the cathode. The author describes two species of positive rays due to the light electric effect.—*Ann. der Physik*, No. 11, 1909, pp. 137–165.

J. T.

8. *Electricity excited by the fall of Mercury through gases upon the surfaces of metals.*—This paper is of interest to meteorologists and to those who hold to a belief in the theory of contact electricity. The author, A. Becker, lets a fine stream of pure mercury fall through a chamber, filled with certain gases, upon surfaces of different metals, and measures the electric potential. His facts are not in contravention to the arrangement in series of the contact difference of potential of various metals.—*Ann. der Physik*, No. 10, 1909, pp. 909–940. J. T.

9. *Viscosity of Gases.*—Experiments have been conducted in the Jefferson Physical Laboratory for several years by Dr. J. L. Hogg on this subject. These experiments have led incidentally to a comparison of the McLeod gauge and Maxwell's disc method. The latter method appears to be capable of great accuracy, and Dr. Hogg has evaluated the viscosity of the quartz suspending fiber. Gy. Zemplen adopts, to avoid the viscosity of the fiber, a small deflection of a hollow sphere moving in a concentric sphere. He shows the applicability of the formula which he deduced. It was found that the friction coefficient of dry atmospheric air was independent of the rotation velocity (228 seconds to 22 seconds), and that it is greater in moist air in certain limits than in dry air.—*Ann. der Physik*, No. 10, 1909, pp. 869–908.

J. T.

II. GEOLOGY.

1. *The Geology of the Queenstown Subdivision ;* by JAMES PARK. New Zealand Geological Survey, Bull. No. 7 (new series). Wellington, 1909.—This report of 112 pages, with geological maps and numerous excellent photographs, published under authority of Dr. J. M. Bell, Director of the Survey, treats one of the most interesting districts of southern New Zealand, including Lake Wakatipu, in the heart of the mountains between the plains of the eastern slope and the fiords of the western coast. The mountains, 6,000 to 8,000 feet in height, consist chiefly of Paleozoic mica and other schists, compressed into closed overturned folds, so as to give a general monoclinal dip of moderate or small angle to the west. The chief longitudinal valleys are described as established along overthrust shear-planes in the overturned synclines, leaving the overturned anticlines to be less worn down in the ridges ; but the text and maps do not present the facts in sufficient detail to enable the reader to judge of the certainty of these conclusions. Fossiliferous Miocene sandstones are included in one of the closed synclines ; in one locality these beds may be traced, in apparent conformity with the foliation of the schists, from the bottom of a transverse valley at an altitude of 1,800 ft., obliquely up the mountain side to an altitude of 5,300 ft. "Such profound involvement of a thin band of Miocene strata in a highly altered Paleozoic formation seems highly incredible, but the stratigraphical evidence could not be clearer, even if the Tertiary sandstone were a contemporary bed of coal interbedded in the schist" (p. 63). Pleistocene glaciation is described as having been "perhaps without a parallel outside the polar regions" (p. 25), the polar regions of to-day being presumably referred to. All the valley glaciers were united in a "great continental ice-sheet," the surface of which "formed a vast plateau, through which only the tops of the highest peaks appeared." The longest chapter in the report is devoted to Economic Geology ; the gold-bearing lodes being of most importance.

The discussion of certain topics is not so discriminating as might be wished. For example, it is stated that "the lower arm of Lake Wakatipu is doubtless to some extent a rift valley, as may be judged by the dislocation of the schists on the two sides of the lake" (p. 20); yet no evidence is presented to show that the present depression of this arm of the lake is directly dependent on the faulting, as ought to be the case in a rift valley; moreover the structural sections clearly suggest that great erosion has taken place since faulting. If the faulting once produced a depressed trough, later erosion seems to have so profoundly modified this initial form as to require another name than 'rift-valley' for the present form. Again, the discussion of glacial erosion is inconclusive, partly because the author seems to take Ramsay's views on this subject as adequate ; partly because the results reached are presented more in terms of the author's opinion than in terms of critical facts of observation. "It does not necessarily follow that the Wakatipu glacier . . . excavated the rock basin in which the lake now lies. We know that the Wakatipu valley existed prior to the glacial period, and there is good reason for the belief that its origin has a close relationship to the powerful faults that traverse each of the main arms of the lake. . . . It is possible, or perhaps even probable, that a lake occupied a part of the floor of the valley before the advent of the ice" (p. 40). On the contrary, the ample breadth of the lake valley and the moderate declivity of its side slopes show that the powerful faults have no close relation to the valley; and the abundant indications of extensive normal erosion, following the period of mountain folding and preceding the period of glaciation, are strongly against the occurrence of a preglacial lake.

Furthermore, it is by no means demonstrated that "a valley-glacier with a wide bearing-surface relatively to its depth is incapable of exerting a scooping action"; or that "ice can only excavate its bed when the pressure of its mass exceeds the ultimate crushing-strength of the bed rock." Deductions from such postulates as these are not to be trusted. There is unfortunately no sufficient mention of the most critical elements of this problem, namely the form of the lake-valley to-day, which is of much greater value in determining the erosive work done by Pleistocene glaciers than any deductive estimates of glacial erosion can be. Whether glaciers erode their troughs slowly or rapidly, the amount of erosion that they accomplished must be a function of their duration; and as their duration is absolutely unknown, apart from the work that they accomplished, it is better to look at the consequences of their work recorded in their evacuated troughs, than to infer their behavior on theoretical grounds, when the attempt is made to determine what amount of sculpturing they effected. W. M. D.

2. *West Virginia Geological Survey;* I. C. WHITE, State Geologist. Vol. IV. *Iron Ores, Salt and Sandstones;* by G. P. GRIMSLEY. Pp. xv, 603 with 24 plates, 16 figures. Morgantown, 1909.—This volume illustrates the fact that the geological survey of a state can accomplish important results when the reports show what results may be looked for in the future in undeveloped fields. It is divided into three parts, discussing respectively the iron ores, the salt, and the sandstones, including with the latter the glass sand industry. The production of iron ore, which began in 1800 and continued down until 1880, has now ceased entirely in consequence of the introduction of cheaper ores, particularly from the Lake Superior region. The detailed facts given in this Report show, however, that there are extensive ore deposits, particularly suited for the manufacture of open hearth steel, which are available for development in the future, when transportation conditions are more favorable. What is regarded as a conservative estimate gives 140 million tons as the amount probably available in five

counties named. The salt industry of the state has also rapidly declined in recent years, although at Malden and other points it has survived in consequence of the valuable by-products of bromium and calcium chloride. A larger demand in the future is expected.

The treatment of the sandstones follows that of the limestones described in Volume III. The Report contains much valuable information as regards the different occurrences and the tests to which the samples have been subjected. Here also it is noted that a much greater extension of the industry in the state may be looked for.

3. *Geological Survey of New Jersey;* HENRY B. KÜMMEL, State Geologist. Annual Report for the year 1908. Pp. xi, 159, with 21 plates, 6 figures. Trenton, 1909.—In addition to the administrative report, the State Geologist contributes here some further facts on the changes at Manasquan Inlet, and also notes on the mineral industry of the state. The other two parts of the volume are devoted to a general description of the zinc deposits of Sussex County, by A. C. Spencer, and on the building stones by J. Volney Lewis, the latter illustrated by excellent colored plates. The report on the zinc deposits gives some of the results developed by work done in coöperation with the U. S. Geological Survey; the facts are more fully presented in the Franklin Furnace Folio noticed in vol. xxvii, p. 189.

4. *Relations between local magnetic disturbances and the genesis of Petroleum;* by GEORGE F. BECKER. U. S. Geol. Survey, Bulletin 401. Washington, 1909.—The author has been led from a consideration of the different theories for the origin of the natural hydrocarbons, oil, gas, etc., to investigate the possible relations between the distribution of these hydrocarbons and the variation of the compass needle. While some oils are doubtless of organic and others of inorganic origin, the fact that the action of dry ammonium chloride on native iron results in a copious evolution of hydrocarbons, suggests the derivation from carbides of iron or other metals as an important source; it is well known that such carbides exist both in artificial iron and in various meteorites. By plotting the locations of petroleum deposits in the country on a chart showing the isogonic lines for 1905, it is shown that the irregularities in the curves of equal declination are strongly marked in the principal oil regions, and the author regards these coincidences as too numerous to be explained by accident. The relations thus brought out "are compatible with the supposition that the great oil deposits are generated from iron carbides, either by, or without, the agency of water. Of these alternatives the latter is the more plausible. What the map does prove is that petroleum is intimately associated with magnetic disturbances similar to those arising from the neighborhood of minerals possessing sensible magnetic attraction, i. e., iron, nickel, cobalt or magnetite. Henceforth no geological theory of petroleum will be acceptable which does not explain this association."

5. *The Production of Coal in 1908;* by Edward W. Parker.—This advance chapter from the Mineral Resources of the United States for 1908 has been recently issued. It shows that the total amount of coal produced in the country aggregated nearly 416 million short tons. This amount is less than the production of 1907, in consequence of the business depression, by some 65 million tons, but is greater than that of any year preceding, even 1906. Of the total amount produced, one-fifth was Pennsylvania anthracite and the remainder bituminous coal. The details in regard to the different regions are given in this pamphlet.

6. *The Carnivora and Insectivora of the Bridger Basin, Middle Eocene;* by W. D. Matthew. Memoirs Amer. Mus. Nat. Hist., Vol. IX, Part VI, pp. 291–559, with Pls. XLIII–LII and 118 figures in the text.—This is the most important memoir on fossil mammals that has appeared in years and probably none is better fitted than Dr. Matthew to carry out the task. It will prove of the utmost value to all students and workers among the Eocene Mammalia. The material upon which the monograph is based is largely contained in the American Museum and is the result of collections made during the years 1903–6. Comparison has of course been made with the type material in the Yale, Princeton, and National Museums.

The recent collections were made with such care that it is possible to discuss at length the five distinct stratigraphical and faunal horizons into which the Bridger formations are divided, with a table of their entire mammalian contents. The conditions of deposition are next described, followed by a discussion of the relationships and adaptations of the fauna as a whole, emphasizing particularly the degree of brain development which proved so important a factor in the evolution of the various races. The second section is given up to a study of the carnivorous types, and, after a general discussion of the characteristics, adaptations and relationships of the several families, each with its included genera and species is defined in detail. Section III treats of the Insectivora in the same manner. The fourth section includes a discussion of the valne of the astragalus, upon which the author lays great stress, in classification, a bibliography of 119 titles, and a most copious index. R. S. L.

7. *A Pliocene Fauna from Western Nebraska;* by W. D. Matthew and Harold J. Cook. Bull. Amer. Mus. Nat. Hist., Vol. XXVI, Art. XXVII, pp. 361–414, with 27 text-figures.—A summary of the results of an expedition sent out by the American Museum during the summer of 1908. The fauna, which is large and varied, is intermediate between the Blanco and the typical Upper Miocene and is equivalent to the Pikermi of Europe. It differs from the Upper Miocene, to which it is most nearly allied, (1) in the presence of more advanced species or mutations of the several phyla, and (2) of certain Pleistocene or modern genera not hitherto recorded from the Tertiary, (3) in the greater

abundance and variety of three-toed horses, certain species of which show distinct approach to the Pleistocene *Equus* and *Hippidion*, and (4) in the abundance of gigantic camels of the genus *Pliauchenia*. A new genus, two new sub-genera and a number of new species are described. R. S. L.

8. *The Vertebrata of the Oligocene of the Cypress Hills, Saskatchewan;* by LAWRENCE M. LAMBE, F.G.S., F.R.S.C. Contributions to Canadian Paleontology, Vol. III (quarto), Part IV, pp. 1–64, with Pls. I–VIII and 13 text-figures.—In the introduction, Mr. Lambe gives a brief sketch of the discovery of the Cypress Hills Tertiary beds, from which collections were made for the Canadian Geological Survey in 1883, '84, '88, and '89, and finally by Lambe himself in 1904. The collections previous to the last were described by Professor Cope, his final report appearing in 1891 as part of the present volume.

The Cypress Hills deposits are correlated in a general sense with the Oligocene Titanotherium beds, some of the upper members being possibly synchronous with the Oreodon beds. Whether or not the time-equivalents of the Protoceras levels are here represented is problematical. In all over fifty species are described, of which more than half are new. They consist of fishes, reptiles, and mammals, the latter including a marsupial, ungulates, rodents, and carnivores. The plates are the result of the author's beautiful brush work. R. S. L.

9. *Commissão de estudos das Minas de Carvão de Pedra do Brazil. Relatorio Final, Parte II, Mesosaurus braziliensis, nov. sp. do Permiano do Brazil;* by J. H. MACGREGOR, 1908, pp. 302–335 and 5 plates.—This reptile was collected in the bituminous shales in the state of Paranda, southern Brazil, and is interesting from two viewpoints: first in its adaptation to aquatic life, being the first known reptile to forsake the land and return to the habitat of its remote ancestors. The second feature of interest is its reference to a genus hitherto known only from the Permian of South Africa, and in fact indistinguishable from it, which is further evidence for ancient land connection between the two southern continents. R. S. L.

10. *The Skull and Dentition of an extinct Cat closely allied to Felix atrox* Leidy; by JOHN C. MERRIAM. Univ. of Cal. Pub., Bull. Dept. Geol., Vol. V, No. 20, pp. 291–304, with pl. 26.—This huge cat is one of the remarkable assemblage of Quaternary animals from the asphalt death trap on the Rancho la Brea, near Los Angeles. The general form of the skull is remarkably similar to that of the recent African lion and to the cave lion of the European Quaternary. The immense size may be realized from the measurements; among which the length is given as 395^{mm}, or about 15½ inches. R. S. L.

11. *Teratornis, a new Avian Genus from Rancho la Brea;* by LOYE H. MILLER. Ibid., Vol. V, No. 21, pp. 305–317.—This great raptorial bird from the asphalt deposits is much larger than either the bald eagle or the California buzzard, and repre-

sents one of a large group of birds of prey which evidently came to feast upon the unfortunate animals entrapped in the asphalt. Teratornis, while showing a preponderance of characters which would tend to link it with the vultures, is considered as representing a distinct family, the Teratornithidæ. R. S. L.

12. *Igneous Rocks. Vol. I, Composition, Texture and Classification;* by JOSEPH P. IDDINGS. Pp. 464, 8vo, 22 cuts and figs. and 2 pls. New York, 1909 (Wiley & Sons).—It is promised that a second volume will be devoted to the description and occurrence of igneous rocks, this first one being confined to what may be called the theoretical aspect of the subject. In accordance with this the first chapter deals with the chemical composition of igneous rocks, or magmas, and the various means which have been used for diagrammatically representing chemical relations among rock-groups, and of graphically picturing rock analyses. This is followed by one in which the chemical composition of the pyrogenetic minerals is treated. The third chapter is especially timely and significant in that it presents in clear, succinct form those principles of chemistry and physics which are applicable to rock magmas and their solidification into rocks. In this the latest views of physical chemistry which apply to the subject are given, and many petrographers, students and teachers alike, will find this one of the most useful and important chapters in the volume. The more igneous rocks and the pyrogenetic minerals are studied the more evident it becomes that rock magmas are mixed solutions and that the general laws obtained from recent studies in physical chemistry are applicable to them, as well as to the solutions usually studied in the laboratory, modified by the conditions of high temperature. The author here gives full credit to the illuminating work now being carried out in the Geophysical Laboratory of the Carnegie Institution. This chapter is followed by one dealing with the chemical reactions which take place in magmas; the chemical composition of the important minerals and their formation and relation to one another are considered. After this the separation of substances from solutions is discussed, and here the work of Vogt on slags and of others in the field of physical chemistry are treated in their relation to the problem in hand. Especially in its presentation of the rôle of eutectics will this chapter be found of value.

Following these matters of underlying and fundamental importance the actual crystallization and the texture of igneous rocks are described. In respect to the latter feature the author uses and amplifies the descriptive terms proposed not long since by himself and several other American geologists in the Journal of Geology (vol. xiv, p. 692, 1906).

The seventh chapter deals with the differentiation of igneous rocks and under this heading a variety of subjects, such as petrographic provinces, pegmatites, facies of rocks, hybrid rocks, order of eruption and complementary rocks, is treated. This is succeeded by one devoted to a description of the various modes in which igneous rocks occur as geological bodies.

The second part of the work considers the nomenclature and classification. After a short historical sketch the author presents a qualitative mineralogical classification which is based in essence on the quantitative classification in that the rocks are divided first into five groups, as follows: 1, chiefly quartz; 2, quartz and feldspar; 3, feldspar; 4, feldspar and feldspathoid; 5, chiefly feldspathoid. These are subdivided according to the nature of the feldspars into A, alkalic feldspars; B, calci-alkalic feldspars; C, soda-calcic feldspars, and each of these has a subdivision according to whether there is much or little ferromagnesian mineral; a final group contains the rocks without feldspars. Under these divisions the rocks, under the names ordinarily used, are grouped, and while many names fall into certain compartments it is interesting to observe that not many of the rock kinds ordinarily recognized under the rather loose groupings now employed, have to be split up. There is of course a further division under texture and in the text explaining the table cenotypal and paleotypal habits are recognized.

The volume closes with a full statement of the quantitative classification as previously presented by the author and others.

This volume in many respects, some of which have been indicated above, is the most important treatise on the theoretical side of petrography which has yet appeared. It should be in the hands of every teacher and advanced student of the subject. In comparison with the work of Mr. Alfred Harker, also noticed in this Journal, it is interesting to observe the different standpoints of the two men. While the subject matter covered is essentially the same in each work, Professor Iddings's standpoint is chiefly the physico-chemical one, while Mr. Harker lays weight on the geological aspect. Thus to draw a comparison from biology, one work is chiefly anatomical, the other faunal, in its viewpoint. Thus in a measure the two works supplement each other.

The typography, illustrations and general make-up of the volume are excellent and a credit to the well-known firm of publishers which issues it. L. V. P.

13. *Natural History of Igneous Rocks;* by ALFRED HARKER, 8°, pp. 384; 2 pls., 112 diagrams. London, 1909 (The Macmillan Co.).—The author states in his preface that the volume consists in substance of the course of lectures delivered by him in Cambridge University on petrology. He first considers igneous action and igneous rocks from the purely geologic standpoint, and emphasizes this aspect of the subject from the feeling that it has not yet received the recognition it deserves as a part of historical geology. In accordance with this we find the first chapter devoted to igneous action, and after considering various regions the author announces three distinct phases: (1) volcanic extrusions, (2) plutonic intrusions, and (3) minor intrusions. When the

normal cycle is complete, these follow in the order given. The second chapter is devoted to vulcanicity; if earth movements are of two kinds, vertical movements, giving rise to plateau building, and horizontal ones, giving rise to folded mountain regions, then there are two contrasted forms of volcanic eruptions, *fissure* and *central* eruptions, the first connected with plateau-building, the latter with mountain formation. Fissure eruptions are normally quiet and non-explosive, while the central type gives rise to active volcanoes.

The author then takes up the subject of intrusions and these again he divides into two groups, as previously described for extrusions. Laccoliths and sills are normal intrusions in plateau districts, while stocks, batholiths, sheets and dikes are characteristic for folded mountain regions. Curved lenticles of igneous rock occurring in folded beds are termed *phacolites.* After this the subject of petrographical provinces is discussed followed by the mutual relations of associated igneous rocks. Under this Harker states that in volcanic extrusions the law holds that succeeding eruptions are successively more diverse, more acid or more basic, than the initial type, while in the major intrusions the rule is that the most basic type is intruded first and successive ones are more and more acid ; in the phase of minor intrusions the reverse is true, the most acid types are the older, the basic ones, such as the lamprophyres, the younger. Here also the question of increasing divergence arises to produce complexity and serial relationships. In following chapters the writer discusses the chemical composition of magmas, the physical properties of the rock-forming minerals, and the various problems of crystallization which arise from considering the solidification of magmas. These subjects, which are of the greatest interest to petrologists, occupy a considerable portion of the volume and are treated in accordance with the most recent views in physical chemistry. In this phase of the general subject the author mainly follows the ideas of Vogt. Successive chapters on the structure of igneous rocks, on mineralizers and pneumatolysis, and on magmatic differentiation, indicate also the scope of the volume, which closes with an essay on classification. The American quantitative classification the author views with disfavor as being too artificial. He believes that the classification should be a natural one based on the relationships of rocks; he does not show how this is to be given practical form, but leaves this for the future to determine and states certain principles which should govern attempts to formulate a classification.

The work as a whole is an interesting and important contribution in the field of petrology; it contains new ideas and is stimulating and should find a place in the working library of every teacher and worker in this field of science. L. V. P.

14. *Journeys through Korea ;* by B. Koto. Journal Coll. Sci. Imp. Univ. Tokyo, Japan, Vol. XXVI, Art. 2, 1909, pp. 1–207, 36 pls.—This work is the author's second contribution to the

geology and physiography of Korea. The first was published in the same journal in 1903 and entitled "An Orographic Sketch of Korea." This one presents the details of the geological observations made in three traverses across the southern part of the peninsula. The general results are given in a summary with geologic map and section of the route followed. These show that the general trend of the formation lines is somewhat west of south, following the axis of the peninsula. The central axis is composed of an immense area of gneiss flanked in general by schists and sandstones and including masses of eruptive and intrusive igneous rock, granites, porphyries, breccias, etc. The outlying island of Quelpart is volcanic and composed of basalt. A contact facies of a great mass of a rock determined as porphyrite is described as a porphyritic plagioclase greisen and named *masanite.* The plates present a large number of fine views of the country explored. The whole forms a notable contribution to the geology of eastern Asia. L. V. P.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Darwin and Modern Science: Essays in Commemoration of the Centenary of the Birth of Charles Darwin and of the Fiftieth Anniversary of the Publication of the Origin of Species.* Edited by A. C. SEWARD. Pp. xvii, 595, with 5 plates. Cambridge, 1909 (University Press).—Although it is "impossible to express adequately in a single volume . . . . . the influence of Darwin's contributions to knowledge on the subsequent progress of scientific inquiry," yet the papers here published together, each by an expert and dealing with the present condition of his own special field of work, form a most remarkable series of essays. Such of the papers as were originally written in German and French have been rendered into simple English, and the work of the editor has been done with such thoroughness that the whole series forms a continuous and uniform account of the present state of knowledge in a great variety of scientific fields.

The diversity of topics treated and the eminence of the contributors will be seen from the following list of the twenty-nine chapters: 1, Introductory letter to the editor from Sir Joseph Dalton Hooker; 2, Darwin's predecessors, by J. Arthur Thomson; 3, The selection theory, by August Weismann; 4, Variation, by Hugo de Vries; 5, Heredity and variation in modern lights, by W. Bateson; 6, The minute structure of cells in relation to heredity, by Eduard Strasburger; 7, "The Descent of Man," by G. Schwalbe; 8, Charles Darwin as an anthropologist, by Ernst Haeckel; 9, Some primitive theories of the origin of man, by J. G. Frazer; 10, The influence of Darwin on the study of animal embryology, by A. Sedgwick; 11, 12, The palæontological record: I. Animals, by W. B. Scott, and II. Plants, by D. B.

Scott; 13, The influence of environment on the forms of plants, by Georg Klebs; 14, Experimental study of the influence of environment on animals, by Jacques Loeb; 15, The value of colour in the struggle for life, by E. E. Poulton; 16, 17, Geographical distribution of plants, by Sir William Thiselton-Dyer, and of animals, by Hans Gadow; 18, Darwin and Geology, by J. W. Judd; 19, Darwin's work on the movements of plants, by Francis Darwin; 20, The biology of flowers, by K. Goebel; 21, Mental factors in evolution, by C. Lloyd Morgan; 22, The influence of the conception of evolution on modern philosophy, by H. Höffding; 23, Darwinism and sociology, by C. Bouglé; 24, 25, The influence of Darwin upon religious thought, by Rev. P. N. Waggett, and on the study of religions, by Jane Ellen Harrison; 26, Evolution and science of language, by P. Giles; 27, Darwinism and history, by J. B. Bury; 28, The genesis of double stars, by Sir George Darwin; 29, The evolution of matter, by W. C. D. Whetham.

The volume thus produced by these distinguished authorities affords an admirably thorough and comprehensive view of the present condition of the broad field of science in which Darwin was interested, and as it is written for the educated layman rather than for the specialist, it commends itself to a wide circle of readers. W. R. C.

2. *Les Zoocécidies des Plantes d'Europe et du Bassin de la Mediterranée;* par C. Houard; 2 vols., pp. 1247, with 2 plates and 1365 text-figures. Paris, 1908 (Lib. sci. A. Hermann).—This great work consists of a descriptive catalogue of all the varieties of malformations, or galls, which are caused by animal parasites on plants growing in Europe and the Mediterranean region. The list includes 6239 different kinds of galls. Most of these are briefly described, and several hundred are illustrated. These galls are produced by nearly 1200 species of insects and 268 species of arachnids. Such malformations are found on a few species of Cryptogams, and on more than 2000 varieties of flowering plants. Among the latter the oaks alone have more than 800 different kinds of galls. The plants are arranged in systematic order and their animal parasites indicated by name so far as known. W. R. C.

3. *Autogamie bei Protisten und ihre Bedeutung für das Befruchtungsproblem;* von Dr. Max Hartmann, pp. 72, with 27 text-figures. Reprinted from the Archiv für Protistenkunde, Bd. xiv, Heft 2, 1909 (Jena).—An interesting and valuable summary and discussion of the facts relating to endogamous conjugation or self-fertilization in the unicellular animals and plants. L. L. W.

4. *Les Observations Méridiennes;* par F. Boquet. Tome I, Instruments et Méthodes d'Observation, pp. 314. Tome II, Corrections instrumentales et Equations personelles, pp. 342. (Encyclopédie Scientifique, Octave Doin et Fils, Éditeurs, Paris.)—The comprehensive character and high grade of the Scientific

Encyclopedia, founded by Dr. Toulouse, to which these volumes belong, has already been remarked in this Journal. The publishers now present two volumes in the library of Astronomy and Celestial Physics, of which the titles are given above, both by F. Boquet of the Observatory of Paris.

Opening it at random, we are attracted by the article on Self-registering Micrometers, concluding with a description, clear as the French language can make it, of the latest thing in Astronomical Micrometers, the *Micrometer Gautier*, installed in 1903 at the Observatory of Paris, and since then in all leading observatories of France.

An illuminated thread is fixed on the star and travels with it, contact being noted for this thread on a point of reference. Greater accuracy results than by the traditional method of noting contact of the star with a fixed thread. W. B.

5. *Ostwald's Klassiker der Exakten Wissenschaften.* Leipzig, 1908 (W. Engelmann).—Recent additions to this important series are the following:

No. 166. Entladung der Leidener Flasche; intermittierende, kontinuierliche, oszillatorische Entladung und dabei geltende Gesetze. Abhandlungen von W. FEDDERSEN (1857–1866). Herausgegeben von TH. DES COUDRES. Pp. 130, 3 plates and portrait.

No. 170. Abhandlung über die Glycole oder zweiatomige Alkohole und über das Aethylenoxyd als Bindeglied zwischen Organischer und Mineralchemie; von ADOLF WURTZ. Aus dem Französischen übersetzt und mit Anmerkungen versehen von M. u. A. LADENBURG. Pp. 95, text figure.

6. *Catalogue of the Lepidoptera Phalænæ in the British Museum.* Volume VIII. *Catalogue of the Noctuidæ;* by Sir GEORGE F. HAMPSON. Pp. xiv, 583, with 162 figures; also plates cxxiii–cxxxvi. London, 1909.—This eighth volume of the British Museum Catalogue of Moths is devoted to the second part of the Noctuid subfamily *Acronyctinæ.* It includes 104 genera with 702 species, while the seventh volume (see v. xxvii, p. 492), which preceded, contained 96 genera with 843 species. There remain 171 genera, which will be discussed in the final part of the subfamily, soon to appear. The text is accompanied by a volume of beautifully executed plates illustrating the species described.

7. *Les Prix Nobel en 1906.* Stockholm, 1908 (P. A. Norstedt & Sons).—This recently issued volume presents the facts in regard to the distribution of the Nobel prizes of 1906. It gives portraits and biographical notices of the recipients, and representations of the Nobel medals and diplomas. The prizes in science were awarded to Joseph John Thomson and Santiago Ramon y Cajal in Physics, to Henri Moissan in Chemistry, and to Camillo Golgi in Physiology and Medicine. The volume closes with the lectures delivered at Stockholm, in December 1906, by J. J. Thomson, C. Golgi and Santiago Ramon y Cajal.

Obituary.

Dr. Joseph Frederick Whiteaves, LL.D., F.G.S., F.R.S. the distinguished paleontologist to the Geological Survey of Canada, died at his home in Ottawa on August 8 last, in his 74th year. Born in Oxford, England, on the 26th of December, 1835, he was early attracted to the pursuit of Natural History in his native city, and began by collecting the land and freshwater shells of the neighborhood. Later most of his time was devoted to collecting and studying the Jurassic fossils of the country around Oxford. In 1861, Dr. Whiteaves arrived at Quebec, Canada, and then proceeded to Montreal, where he became acquainted with Elkanah Billings, paleontologist of the Canadian Geological Survey. From 1865 to 1875, he was Curator of the Museum of the Society of Natural History at Montreal, publishing papers in the meanwhile on the land and freshwater mollusca of Lower Canada, the Ordovician fossils of the Island of Montreal, and the living marine invertebrates of the Gulf of St. Lawrence. In 1875, he joined the Geological Survey of Canada as associate paleontologist with Elkanah Billings, succeeding in 1876 to the office of paleontologist, a position he held up to the time of his death. In 1883 he received the additional appointments of zoologist and assistant director. During these thirty-four years of service he published more than 100 papers on Canadian paleontology and zoology.

Dr. Whiteaves was one of the original Fellows of the Royal Society of Canada, and was an active Fellow of the American Association for the Advancement of Science between 1882 and 1899, and Vice President of its section of Geology and Geography in 1899. In 1900 he received the degree of LL.D. from McGill University, Montreal. His chief work has been in making known the stratigraphy and paleontology of western Canada. C. S.

Hugh Fletcher, geologist of the Canadian Government, died of pneumonia, September 23d, at Lower Cove, Cumberland, Nova Scotia. He was born at London, December 9, 1848, and came to Canada in 1863. In 1872 he joined the Geological Survey of that country, after taking the B.A. degree at Toronto the previous year. During his thirty-seven years of active geological service he did much to develop the mineral resources of Nova Scotia, especially the coal deposits. His official reports are voluminous, carefully prepared and detailed. He stood high among the mining men of Nova Scotia, and also among American geologists. He leaves a son and daughter. C. S.

Dr. Anton Dohrn, the eminent zoologist who founded and as director developed the Biological Station at Naples, died at Munich on September 26 at the age of sixty-eight years.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XLVII.—*The Ordovician and Silurian Formations in Alexander County, Illinois*;* by T. E. Savage.

Location and Earlier Work.

Rocks of Ordovician and Silurian age are exposed in southwest Illinois only over a narrow belt, less than four miles in maximum width, bordering the Mississippi river. The line of outcrop of these strata extends along the west side of Alexander county, and continues north about two miles into the southwest corner of Union.

For almost forty years practically no work was done on these horizons in this portion of the state. In 1866, Worthen† described a bed of massive, light gray, semi-crystalline limestone, outcropping near Thebes, as the lowest strata exposed in this part of Illinois, and correctly referred it to the Trenton (=Mohawkian) series. Concerning the Cincinnatian strata in this region he says:‡

"They consist of about 100 feet in thickness of brown, sandy shales and regularly bedded, brown sandstone (Thebes sandstone and shale) which forms the lower portion of the group; overlain by about forty feet of thin-bedded, compact, fine-grained limestone—which breaks with smooth, conchoidal fracture" (Cape Girardeau limestone).

Under the name Clear Creek limestone§ he described a group of siliceous limestones in this region which immediately succeed the Girardeau. These he interpreted as occupying the same stratigraphic position as the Niagara dolomites in the northern part of the state.

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* Published by permission of the Director of the Illinois Geological Survey.
† Worthen: Geol. Surv. Ill., vol. i, p. 148.
‡ Ibid., p. 139.
§ Ibid., p. 126.

In 1868 there was published a detailed report on the geology of Union and Alexander counties,* based on the studies of A. H. Worthen and Henry Englemann. In this work the divisions of the Ordovician remain unchanged, but the term "Clear Creek limestone" is restricted to only that part of the siliceous limestones which is correlated with the Oriskany series of the Devonian. To the Silurian there is referred the lower 250 feet of these deposits under the name Lower Helderberg limestone.

In this report Worthen referred the so-called Lower Helderberg limestone to a horizon higher than that of the Niagara dolomites in northern Illinois. In 1870 he reverted to his earlier views and correlated these limestones with the Niagara dolomites farther north,† explaining the difference in the specific character of the fossils in the respective deposits as "entirely due to the difference in the oceanic conditions under which they were laid down and not to the different ages of the sediments themselves."

Since 1870 no careful study of the above mentioned beds has been made until detailed work was taken up by the writer during a part of the summers of 1907 and 1908. In the collection of fossils the exposed ledges were worked by layers, or arbitrarily divided into zones from six inches to a very few feet in thickness. The fossils from each of these layers or zones were kept separate in order to determine the vertical range and the relative abundance of the different species. This detailed manner of work has revealed the presence of a surprising number of unconformities, some of which would not have been detected by any marked change in lithology, or by a less careful method of study. In a preliminary statement of the results of this work, a general section of the deposits has been given.‡

Conditions of Deposition.

The strata under consideration were laid down in an arm of the sea which had connection southward with the Mexican gulf region along a depression now occupied by the lower course of the Mississippi river. Up this embayment the sea pulsated backward and forward. Through the southward connection the successive faunas reached the part of the basin under consideration and spread towards the north, east and west, to a greater or less distance, with increasing or decreasing depth of the water. A short distance to the west of

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* Worthen: Geol. Surv. Ill., vol. iii, p. 20 et seq.

† Worthen: Proc. Am. Assoc. Adv. Sci., vol. xix, pp. 172–175.

‡ Savage, this Journal, vol. xxv, pp. 431–443, 1908; also, Ill. State Geol. Surv., Bull. No. 8, pp. 103–117, 1908.

this area the embayment was bordered by the Ozarkian land mass. On account of the proximity of the shore, the sea was generally shallow, so that even minor movements were registered in the deposits. As a consequence of these conditions there occur here a surprising number of breaks in sedimentation, recording a remarkable number of oscillations of level during the Ordovician and Silurian periods; and during the interval, generally represented by land conditions, between the deposition of the uppermost Richmond beds and the basal deposits of the Clinton.

Succession of Strata.

The relations of the various formations representing the Ordovician and the Silurian Systems in this region are shown in tabular form below:

Silurian	Clinton	Sexton Creek limestone, 16–70 feet
	Alexandrian	Edgewood limestone, 0–12·5 feet
		Girardeau limestone, 18–33 feet
Ordovician	Cincinnatian	Orchard Creek shale, 17–22 feet
	Mohawkian	Thebes sandstone, 75 feet
		Fernvale limestone, 0–3·5 feet
		Kimmswick limestone, 70–82 feet

ORDOVICIAN SYSTEM—MOHAWKIAN SERIES.

Kimmswick Limestone.

The name Kimmswick was applied by Ulrich* to a bed of gray, thick-bedded, subcrystalline limestone exposed in the vicinity of Kimmswick, in Jefferson county, Missouri. These beds correspond in their lithology and fauna with those appearing in the railroad cut and river bank a short distance south of Thebes, which Worthen referred to the Trenton. The above name is retained for these strata in southwest Illinois which contain the fossils *Receptaculites oweni*, *Dalmanella testudinaria rogata*, *Platystrophia biforata*, *Rafinesquina alternata*, *Parastrophia hemiplicata*, *Strophomena trentonensis*, *Rhynchotrema inæquivalve*, *Zygospira recurvirostra*, *Bronteus lunatus*, *Bumastus trentonensis*, *Illænus americanus*, *Isotelus* cf. *maximus*, *Platymetopus cucullus* and *Remopleurides striatulus*.

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*Ulrich: Mo. Bur. of Geol. and Mines, vol. ii, 2d series, p. 111, 1904.

The outcrop of this formation is limited to a few small patches in the bank and bed of the river, in the vicinity of Thebes. The Kimmswick beds differ in their lithology and fauna from those of any horizon in the Mohawkian series in the northern portion of the state, with some part of which they were doubtless contemporaneous. A barrier of some kind probably separated the two areas during the time of deposition of the respective beds.

Correlation.—Out of thirty-five species of fossils listed from the Mohawkian strata of Minnesota* which are also found in the Kimmswick limestone of Illinois, nine appear below the Trenton, six of which persist into the lower Trenton beds; twenty occur in the lower division of the Trenton (Clitambonites bed), nine of which continue upward into the overlying division; twenty-four species occur in the middle division (Fusispira bed); while only a single one of these is found in the upper division (Maclurea bed). From these facts the Kimmswick limestone is thought to correspond, in time, with some part of the middle division of the Trenton (Fusispira bed) of the upper Mississippi valley.

The Post-Kimmswick Unconformity.

An erosion interval succeeding the deposition of the Kimmswick limestone is shown in the fact that the thickness of this limestone varies from place to place, and the upper portion of the formation is not a constant horizon. Land conditions are also indicated in the presence, at the top of the formation at Cape Girardeau and other points, of solution channels filled with red colored, residual clay. The time involved in this erosion period was long. Some of the upper part of the Mohawkian and all of the Utica and Lorraine deposits are wanting.

CINCINNATIAN SERIES.

The rocks of the Cincinnatian series in Alexander county are all embraced in the Richmond stage. They comprise three distinct formations: 1, the Fernvale limestone at the base; 2, the Thebes sandstone, and 3, the Orchard Creek shale.

The Fernvale Limestone.

Overlying the Kimmswick strata is a thin bed of hard, gray limestone, bearing *Rhynchotrema capax*, *Dinorthis subquadrata* and other fossils characteristic of the lower portion of the Richmond stage. Strata containing similar fossils have

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* Geol. and Nat. Hist. Surv. of Minn., vol. iii, pts. 1 and 2.

been described by Ulrich and Hayes,* for which the name Fernvale was proposed, from the town of Fernvale, in Williamson county, Tennessee. From the similarity of the fossils in the two areas this limestone overlying the Kimmswick formation in the vicinity of Thebes is considered the equivalent of the Fernvale beds in Tennessee, and the name of the Tennessee locality has been used to designate this basal Richmond formation in Alexander county.

This horizon is exposed at only two points, at each of which the area of outcrop is very limited in extent. A thin zone may be seen on the top of the Kimmswick blocks in the bed of the river, one-fourth mile north of Thebes. A thickness of three and one-half feet of this limestone occurs immediately underlying the Thebes sandstone† in the south part of the town of Thebes.

Among the fossils found in this limestone are bulbous crinoid segments, *Dinorthis subquadrata*, *Hebertella insculpta*, *H. occidentalis*, *Platystrophia acutilirata*, *Plectorthis whitfieldi*, *Rafinesquina alternata*, *Rhynchotrema capax*, *Strophomena fluctuosa* and *S. planumbona*.

Correlation.—The continuity of the Richmond sea in Illinois and Iowa was apparently broken by a number of low land barriers extending in a general northeast-southwest direction. The sediments of this age in Iowa and northwest Illinois have been called the Maquoketa beds. The sea in which they were laid down was not broadly connected with that in which the Richmond beds in the southern and eastern parts of the state were deposited. For this reason exact correlation of horizons in the two areas is as yet difficult.

In the Maquoketa beds of Fayette county,‡ Iowa, *Rhynchotrema capax* occurs at three successive horizons. It is found first in the lower Maquoketa division, in beds of alternating shale and impure limestone, a short distance above the zone of *Nileus vigilans* (No. 5 of the general section on page 485 of the Fayette County report). The second appearance is in the limestone or dolomite which constitutes the middle division of the Maquoketa beds, while the third occurrence is in the alternating shale and limestone layers near the top of the upper Maquoketa beds. Among the fossils associated with *Rhynchotrema capax* in the lowest horizon are *Dinorthis sub-*

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* Ulrich and Hayes; The Columbia Tennessee Folio, No. 95, U. S. G. S., 1903.

† Note: The position of this horizon is immediately below 2a of the general section given in the preliminary statement. (This Journal, vol. xxv, p. 443, 1908.) It was not noted in that paper because its presence had not been detected, nor had it previously been recognized in this portion of the state.

‡ Savage: Iowa Geol. Surv., vol. xv, pp. 484–486.

quadrata, *Hebertella insculpta*, *Plectorthis whitfieldi*, *Strophomena fluctuosa* and *S. planumbona*. Only one of these recurs in either of the higher horizons. From these considerations the Fernvale formation of southern Illinois is thought to correspond, in time, with the lower *Rhynchotrema capax* horizon of the Maquoketa beds in Fayette county, Iowa.

Outside of this region the Fernvale formation is known in Illinois from Monroe county; and it has also recently been recognized by the writer in the vicinity of Millsdale, and again two miles further north, in Will county.

The Post-Fernvale Unconformity.

The presence of an unconformity between the Fernvale limestone and the overlying sandstone is shown in the fact that at some points in adjacent portions of Missouri the Thebes sandstone formation rests upon the weathered surface of the Kimmswick beds, the Fernvale strata being entirely absent. A considerable movement is also indicated in the change from the limestone strata of the Fernvale to the sandstone of the succeeding formation.

The Thebes Sandstone.

The name "Thebes sandstone" was given by Worthen to the chocolate-colored sandstone and sandy shale which is well developed and favorably exposed in the town of Thebes. The formation is separated by its lithology and fauna, and also by an erosional unconformity, from the Fernvale limestone upon which it rests, and from the overlying calcareous shale. In its lower part the strata consist of a few feet of fine, slightly shaly sandstone, above which the beds become more massive and the texture more coarse. In the upper portion the material weathers into thin flakes or flaglike layers, and contains a small admixture of shale. The thickness of the formation is about 75 feet. This sandstone carries a meager fauna. In a narrow zone near the base trilobite fragments are very abundant, but throughout the greater portion of the thickness an occasional shell of *Lingula covingtonensis*, and branches of *Climacograptus putillus* are the only fossils that are encountered.

The Thebes sandstone is exposed over a much larger area in this region than any of the preceding formations. It has also recently been found to have a much wider distribution in the state than was formerly supposed.

The Post-Thebes Unconformity.

Evidence of a break in sedimentation closing the deposition of the Thebes formation appears in the abrupt change in the lithology, and in the fauna, in passing from the Thebes sandstone to the succeeding deposits. It is shown in a strongly weathered and iron-stained zone at the top of the Thebes formation; and in the fact that in different exposures the succeeding deposits rest upon different levels of the Thebes sandstone.

The Orchard Creek Shale.

The name Orchard Creek shale is here proposed for a bed (=2b of my generalized section of 1908) of calcareous shale exposed in the banks of Orchard creek, about two miles south of Thebes. The formation is embraced between the Thebes sandstone below and the Girardeau limestone above. The material consists of bands of bluish-gray shale, four to six inches thick, alternating with two- to four-inch layers of impure, concretionary limestone. The maximum thickness of the bed is about twenty-two feet.

An exposure of this shale, underlying the Girardeau limestone, may be seen near the mouth of Orchard creek above mentioned. It appears, above the Thebes sandstone, along the bank of the river, and in the cut along the Chicago and Eastern Illinois railroad, between Thebes and the village of Gale.

The more characteristic fossils of this horizon are *Cyclocystoides* cf. *illinoisensis*, *Phylloporina granistriata*, *Dalmanella meeki*, *Leptæna rhomboidalis*, *Rafinesquina alternata*, *Rhynchotrema* cf. *inæquivalve*, *Strophomena* near *incurvata*, *Zygospira recurvirostra*, *Cornulites tenuistriata*, *Conradella*, *imbricata*, *Pterinea thebesensis* and *Isotelus* sp.

More than one-half of the species certainly identified from this formation have not been reported from any other locality. A number of them are recurrent Mohawkian forms. The fauna lacks the characteristic Richmond fossils, but the presence of earlier types is not unusual in the Richmond strata. The position of these beds, above the Fernvale and the Thebes sandstone, refers the horizon certainly to the higher Richmond.

The Post-Orchard Creek Disconformity.

No well marked line of unconformity separates the Orchard Creek shale from the overlying Girardeau limestone. However, such a sedimentary break is indicated by the great difference between the faunas of the two formations. Out of sixteen species collected from the Orchard Creek shale and twenty-seven species from the Girardeau limestone, only three are common to the two horizons. These are *Leptæna rhomboidalis*, *Cornulites tenuistriata* and *Pterinea thebesensis*, all long-ranging species. This almost total change in the fossils, accompanied by no abrupt change in the lithology, is considered deciding evidence of a land interval between the time of deposition of the respective beds.

SILURIAN SYSTEM—ALEXANDRIAN SERIES.

The term Alexandrian Series has been proposed* to include those strata which more or less completely bridge the interval between the uppermost horizon of the Richmond and the basal deposits of the Clinton. They carry faunas intermediate in character between the Richmond and the Clinton, but not distinctively those of either group.

The formations in southern Illinois that contain faunas which cannot properly be referred to the Richmond below, or the Silurian above, but which have affinities in both directions, are: 1, the Girardeau limestone, and 2, the Edgewood formation.

The Girardeau Limestone.

Strata of this age were first described by Shumard,† in 1855, from Missouri under the name Cape Girardeau limestone. Worthen recognized the horizon in southwest Illinois and retained Shumard's name for the formation.

The rocks consist of dark-colored, fine-grained, compact, brittle limestone, in imperfectly separating layers two to five inches thick. Between the layers occur thin lenses of hard, calcareous shale which locally contain numerous fossils. Among the common species are *Glyptocrinus fimbriatus*, *Tanaocrinus* cf. *typus*, *Camarotœchia scobina*, *Dalmanella* near *elegantula*, *Homœospira* sp., *Leptæna rhomboidalis*, *Rafinesquina mesacosta*, *Schuchertella missouriensis*, *Waldheimia* (?) *bicarinata* var., *Cyclonema cancellata*, *Platyostoma niagarensis* var., *Cyrtodonta primogenia*, *Pterinea thebesensis*, *Acidaspis halli*, *Cyphaspis girardeauensis*, *Encrinurus deltoideus* and *Lichas* sp.

The maximum thickness of the formation in Illinois is about thirty-three feet. The strata are well exposed in the banks of a creek two miles south of Thebes, and also along the river one-half mile further south. North of Thebes they outcrop along the Chicago and Eastern Illinois railroad, one-half mile south of Gale.

The Girardeau a transition fauna.—The fauna of the Girardeau limestone, listed above, has a decidedly Silurian aspect. The genera Homœospira, Schuchertella, Waldheimia? and Platyostoma are distinctively Silurian, while not one of the species could be considered a marker of a Richmond horizon. A few of the Ordovician forms persist, but the

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* Savage: This Journal, vol. xxv, p. 434, May, 1908.

† Shumard, B. F.: 1st and 2d Ann. Repts. Geol. Surv. Mo., p. 109, 1855.

presence of new Silurian types in the fauna is of much greater significance than the lingering of a few Ordovician species. Hence the formation is thought to represent early Silurian time.

Although the fauna of the Girardeau limestone shows distinctly Silurian characters, it cannot be assigned to any recognized horizon in the Clinton. The Sexton Creek beds, which in this region succeed the Edgewood formation overlying the Girardeau, are thought to represent a Clinton horizon as low as any previously described. Hence it seems most conducive to a clear statement of the facts to refer the Girardeau and the succeeding Edgewood formation to a distinct time interval earlier than the Clinton, called the Alexandrian, by which the post-Richmond and pre-Clinton age of the beds, as shown by their stratigraphic position and by the transitional character of the faunas, is clearly indicated.

The Post-Girardeau Unconformity.

Clear evidence of an erosion interval succeeding the deposit of the Girardeau limestone appears in an exposure in the bank of the river three-fourths mile south of Gale. The strata here which are next younger than the Girardeau limestone rest on the very basal portion of this formation, three feet above the top of the Orchard Creek shale. That a considerable thickness of the Girardeau limestone was originally present here is shown in the fact that at a distance of only twenty rods north a thickness of thirteen feet of this limestone is exposed, and at a less distance to the south a ledge, apparently in place, may be seen in the river bank to a height of five and six feet.

The Edgewood Limestone.

The name Edgewood limestone is here applied to the strata in this region lying above the Girardeau limestone and below the Sexton Creek formation. In my paper of 1908 these are referred to as beds 3b and 3c. The name is taken from the town of Edgewood in Pike county, Missouri, near which place occur strata that have furnished fossils of this horizon in great abundance. In Alexander county the Edgewood beds are exposed in the bank of the river three-fourths mile south of Gale, where they occupy a channel eroded in the Girardeau limestone. A thin band of this limestone may also be seen in an abandoned quarry, one-fourth mile southeast of Gale. At the former locality there is a conglomerate at the base, composed of fragments of Girardeau limestone. This is succeeded by a few feet of fine-grained limestone, and dark, calcareous shale. At the top is a massive layer of hard, gray, coarsely granular limestone, four feet in thickness, which is locally oolitic in the upper part.

The dark shalemember furnished the fossils *Clorinda* sp., *Rafinesquina mesacosta*, coarsely plicate shells of *Schuchertella subplanus*, and *Dalmanites danæ.* The massive upper layer yielded *Clathrodictyon vesiculosum*, *Atrypa putilla*, *Clorinda* sp., *Leptæna rhomboidalis*, *Rhynchotreta thebesensis*, *Schuchertella subplanus*, *Spirifer* cf. *sulcatus*, *Whitfieldella billingsana*, *Pterinea thebesensis*, *Dalmanites* sp., *Prœtus determinatus* and *Lichas clintonensis.* The exposure in the abandoned quarry, near Gale, furnished the following additional species: *Calapœcia* sp., *Lyellia thebesensis*, *Atrypa marginalis*, *Plectambonites transversalis* and *Rhynchonella janea.*

The Post-Edgewood Unconformity.

A break in sedimentation between the Edgewood and the succeeding deposits is shown at the abandoned quarry, near Gale, where the Edgewood limestone is separated from the basal portion of the Sexton Creek beds by a two-inch band of red, residual clay.

THE NIAGARAN (CLINTON) SERIES.

Sexton Creek Limestone.

The name Sexton Creek limestone is here proposed for Silurian strata in this region, which represent some portion of the Clinton time. The name is taken from Sexton creek, one and one-half miles north of Gale, in Alexander county, along which stream these beds are well exposed. In my paper of 1908 these beds are referred to as 4a, 4b, and 4c.

Ulrich* has proposed the name Bainbridge limestone for the Silurian strata appearing in the river bluffs for some miles above and below Bainbridge, Missouri. He states that it is nearly the equivalent of the Clifton limestone of Tennessee (later than Clinton), and that it also occurs in the vicinity of Thebes, Illinois. The present studies have shown that the Silurian strata in the vicinity of Thebes are of Clinton age, or earlier, and hence cannot be correlated with beds in Missouri representing the horizon of the Clifton limestone in Tennessee.

The lower part of the Sexton Creek formation consists of hard, gray limestone, in layers four to eight inches thick, which are separated one from another by two- to four-inch bands of

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* Ulrich: Mo. Bur. Geol. and Mines, vol. ii, 2d series, p. 110, 1904.

chert. This chert-bearing phase is succeeded by thicker layers of pink or reddish, mottled, subcrystalline limestone.

In the upper part the cherty limestone contains *Favosites favosus*, *Halysites catenulatus*, *Atrypa marginalis*, *Orthis flabellites*, *Plectambonites transversalis*, *Stricklandinia triplesiana*, *Triplecia ortoni* var. and *Illænus* cf. *daytonensis*. The strata are well exposed along Sexton creek, one and one-half miles north of Gale. They appear in the river bluff between Gale and McClure; and they may also be seen in the bank of the river two and one-half miles south of Thebes. The maximum thickness of the formation is about seventy feet. The species of fossils listed above indicate that the Sexton Creek limestone represents the westward extension of the Clinton strata occurring in Indiana and Ohio.

The Post-Sexton Creek Unconformity.

After the deposition of the Sexton Creek beds, land conditions prevailed over this area for the greater portion of the time during which the Niagara limestones in the northern portion of the state were laid down. The strata that occur next above the Sexton Creek beds, in this region, represent the Helderbergian series of the Devonian.

Oscillations of level.—Frequent strand-line movements are clearly recorded in the Coal Measure deposits of Illinois, and elsewhere, where a number of coal seams occur in vertical succession, and separated one from another by marine beds of shale or limestone. The numerous oscillations that are shown to have occurred in southwest Illinois, during the late Ordovician and early Silurian times, would indicate that frequent movements were not peculiar to the Pennsylvanian Period. It seems probable that oscillations of level may not have been uncommon throughout the Paleozoic era. The scarcity of such records may be largely due to the fact that the deposits made in shallow water, near shore, are not present over large areas; and that such deposits would be most likely to be removed during subsequent periods of erosion.

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Art. XLVIII.—*The Section at Cape Thompson, Alaska;*[*]

by E. M. Kindle.

Introduction.

Cape Thompson is a promontory on the Arctic coast of Alaska, located about 125 miles north of the Arctic Circle. It is one of a series of bold headlands which face the sea with vertical cliffs 400′ to 700′ high for 6 or 7 miles immediately south of the delta and shore line deposits which lie about the mouth of the Kukpuk River. Alluvial deposits broken by lagoons form the coast line for about 40 miles northwest of Cape Thompson, where the coast line is again formed by cliffs and precipitous hills which continue northward to Cape Lisborne. This portion of the coast is not visited by any of the passenger vessels engaged in Alaskan transportation, but through the courtesy of the officials of the U. S. revenue cutter service and of Capt. Henderson of the revenue cutter Thetis, the writer was enabled to spend a few days during the past season studying the geological section exposed in the vicinity of Cape Thompson. The writer's brief shore leave permitted only the study of the rocks in the immediate vicinity of Cape Thompson and a short trip up the Kukpuk River.

Mr. R. D. Mesler assisted the writer in the field work. Acknowledgments are due to Mr. Jos. Tuckfield and Mr. Jas. Allen, residents of Point Hope, for their unbounded hospitality. The writer's special thanks are also due to Mr. W. Allen Richardson, teacher of the native school at Point Hope, and Dr. John B. Driggs, the veteran missionary, for courtesies extended, and to Capt. White for transportation on the schooner South Bend.

Previous Geologic Investigations.

The geological section at Cape Thompson was examined in 1826 by Mr. A. Collie of Capt. F. W. Beechey's exploring expedition. Lieut. Belcher of the expedition prepared a section of the strata observed, and Mr. Collie collected fossils which led Prof. Buckland to correlate the limestone with the Derbyshire limestone of England.[†] It thus appears that this extremely remote section was one of the first on the continent to be correlated with European sections.

The results of Capt. Beechey's expeditions were summarized by Grewingk,[‡] who states that the fossils from Cape Lisburne

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[*] Published by permission of the Director of the U S. Geol. Survey.

[†] Zoology of Capt. Beechey's Voyage, Bohn, London, 1839, pp. 171–172.

[‡] Grewingk, C., Beitrag zur Kentniss der orographischen und geognostischen Beschaffenheit der Nord-West-Küste Amerikas mit den anliegenden Inseln: Verhandl. Russ.-K. Mineral. Gesell. zu St. Petersburg, 1848 and '49 1850), pp. 160–161, pp. 343–344.

obtained by them were found to be Silurian by Fisher and Kupreanoff. At a much later date a brief note on a slab of fossils from Cape Thompson appeared in a report by Prof. A. Hyatt. These were considered to be "probably Triassic"* by Prof. Hyatt. In 1896 Mr. Chas. Schuchert included in his "Report on Paleozoic fossils from Alaska"† a single species—*Spirifer condor*, which was found on the beach near Cape Thompson by Mr. W. J. Fisher. A. J. Collier published in 1906 a sketch of the section at Cape Thompson as seen from a steamer in passing the Cape.‡

Although mentioned, as noted above, by various subsequent writers, little has been added to the information furnished by Mr. A. Collie's notes published more than three-quarters of a century ago.

The unaltered condition of the rocks here affords exceptional opportunities to secure perfectly preserved fossils in abundance from the Carboniferous limestone, thus eliminating the uncertainty which frequently attaches to the determination of fossils as they are so often found in the highly altered rocks of many parts of Alaska.

General Geologic Relations.

The oldest rocks exposed in the vicinity of Cape Thompson are of Carboniferous age. Rocks of pre-Carboniferous age doubtless underlie most of the delta deposits immediately west and northwest of the Cape, but the outcrops of these rocks, so far as known, do not extend far south of the channel of the Kukpuk River. Along this stream these older rocks, which have been provisionally referred to the Devonian by Collier,§ are well exposed. No fossils have been found in them. They comprise mainly black slates and shales together with sandstones containing some volcanic material with rarely a band of red shale. These older rocks form a belt bordering the Carboniferous limestones on the west to the northwest of the Kukpuk River. Although unknown by outcrops, this belt no doubt reaches the coast beneath the shore line and delta deposits to the west of Cape Thompson.

The rocks exposed in the vicinity of Cape Thompson include both Carboniferous and Mesozoic rocks. The principal structural feature governing the distribution and attitude of the rocks near the Cape is a syncline. The axis of this syncline reaches the coast about two miles southeast of the most north-

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* 17th Ann. Rept., Direct. U. S. Geol. Survey, Pt. I, p. 907, 1896.

† 17th Ann. Rept., Direct. U. S. Geol. Survey, Pt. I, p. 898, 1896.

‡ Geology and Coal Resources of the Cape Lisburne Region, Alaska, Bull. U. S. Geol. Survey, 278, p. 21, 1906.

§ Collier, A. J., Geology and Coal Resources of the Cape Lisburne Region, Alaska, Bull. U. S. Geol. Survey No. 278, p. 17, 1906.

westerly outcrops near Cape Thompson, whence it trends northerly or northwesterly. Near the middle of this syncline along the coast, the rocks lie nearly or quite horizontal for more than a quarter of a mile. From the horizontal they pass gradually into the inclined position, showing dips on opposite sides of the syncline toward its axis. These increase from five or ten degrees nearest the center to a maximum of about 40° on the southeast and 90° on the northwest. This synclinal structure is expressed in the areal distribution of the rocks by two parallel belts of Carboniferous limestone separated by a band of Mesozoic shales one and a half or two miles in width. Toward the south side of the syncline the transition from very slight to steep dips is gradual and progressively uniform from the nearly horizontal Mesozoic shales to the highly inclined limestones, where the dip is uniformly about 35 degrees.

On the west side, however, the uniformity of the syncline is broken up by a local anticline about 300 feet in width, known as agate rock. This minor structural modification of the syncline shows most intricately crumpled and broken beds below the belt of regularly arched strata at the top, which give it the appearance of a typical anticline when seen from a little distance. This local fold is shown in a photograph published by Collier.* The Carboniferous limestones comprising Cape Thompson on the northwest side of the syncline also show marked irregularities in dip. That these irregularities are not evident from a distance is indicated by Collier's† sketch of the section, which was made from the deck of a steamer at a distance of about 3 miles from the Cape. It indicates a uniform westerly dip for the limestones. Nearly the same inclination is indicated for them in the section by Lieut. Belcher‡ of Capt. Beechey's expedition. Instead of a uniform westerly dip, the beds at the Cape are generally inclined toward the east at various angles ranging from 90° to horizontal. The most westerly beds exposed at the Cape include about 400 feet of shales and sandstones which dip toward the east or the axis of the syncline already described at from 80° to 90°. The Carboniferous limestone lying between these basal shales and the Mesozoic beds are generally inclined where observed toward the east at angles ranging from 25° to 90°.

Age of the Formations.

The lowest beds exposed at Cape Thompson outcrop along the beach immediately north of the cliffs. The rocks exposed

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* Collier, A. J., Geology and Coal Resources of the Cape Lisburne Region, Alaska, Bull. U. S. Geol. Survey No. 278, pl. 4, fig. A.

† Bull. U. S. Geol. Survey No. 278, p. 21, 1906.

‡ Buckland, W., Geology and Zoology of Capt. Beechey's Voyage, London, Henry V. Bohn, 1839, pp. 171–174.

in these beach outcrops and the accessible or northern portions of the Cape cliffs are indicated by the following section:

Section 14 at Cape Thompson.

d	Light buff or cream-colored limestone with numerous fossils. Str. about N. S., dip variable, mostly E. 25 to 90′, complicated toward the south.	500′+
c	Black and buff thin-bedded limestone, the former predominating. Productus and large crinoid stems abundant.	380′
b	Bluish gray to black fissile shale with abundant plant fragments. Dip E. 80 to 90°. Str. N. 15 W.	280′
a	Very thin-bedded lead gray sandstone with occasional bands of brown ferruginous chert and films of coal. Plant fragments abundant. Str. N. 15° W. Dip E. 86 to 90°.	140′

The lower 400 feet of the section appears to contain no invertebrate fossils. All or nearly all of these beds represent non-marine sediments. Plant remains in various stages of maceration occur through most of the shales and sandstones below the limestone. Plant fossils were obtained from both *a* and *b* of the section and numbered respectively lots 5289 and 5290. These were submitted to Dr. David White, whose report follows:

"Lot 5289. This lot consists of three fragments of coarse, gray sandstone bearing carbonized impressions of pieces of partially decorticated stems. The characters of the very imperfect impressions point toward a close affinity with *Lepidodendron corrugatum.*

Lot 5290. This lot includes two small packages of wavy, black carbonaceous shale splitting in thin laminae. This shale contains many fragments of leaves of *Lepidodendron*, and unidentifiable, decorticated stem fragments of several kinds, together with several imperfect remains in a better state of preservation. The latter represent *Sphenopteris frigida* Heer, twigs of *Lepidodendron Veltheimianum* as generally identified in the European and Arctic floras, with a cone fragment possibly belonging to the same species, and portions of a *Lepidophyllum* very close to *Lepidophyllum fuisseense* Vaff. There are also present several fragments of a cyclopterid type; these are so incomplete that it is not really possible to decide whether they represent (*a*) rachial pinnules of Neuropteris; (*b*) some large, broad pinnuled *Aneimites;* or, (*c*) pinnules of *Cardiopteris.* I am inclined to refer them to the latter genus.

The plant remains from Cape Thompson are so fragmentary and meager as to determinable species as not to permit a close determination of the age of the beds. They appear to be Mississippian and probably represent a stage in the lower part of this division. They may even come from the basal member thereof."

These plants evidently belong to the same horizon as that from which Collier obtained Carboniferous plants at Cape Lisburne. Concerning the Cape Lisburne plants, Dr. White's report* contains the following statement relative to their age:

"These fossil plants are evidently of Carboniferous age. Owing to the marked scarcity of filicate elements the testimony of the collection is less direct as to precise age than might otherwise be the case. However, from the evidence in hand I am forced to conclude that the plant-bearing terrane is Mississipian, and it appears probable that it is referable to the lower portion of the Mississippian. The flora, especially that of lot 3554, is very closely related to that from Bell Sound and Klass-Billen Bay in Spitzbergen. It seems to be slightly younger than the Ursa flora."

Above the plant-bearing beds only marine fossils are seen. The limestones which follow the sandstone and shales carry an abundant fauna. Corals are quite abundant in the upper division of the limestone series. Dr. Girty has furnished the following list of fossils from these beds:

Lot 14 C.

Fenestella sp.
Cystodictya? sp.
Derbya? sp.
Productus semireticulatus
Reticularia? sp.

Lot 14 D.

Lithostrotion sp. A.
Crinoid stems
Fenestella sp.
Hemitrypa sp.
Stenopora sp.
Cystodictya? sp.
Streblotrypa? sp.
Chonetes sp.
Productus semireticulatus
Productus aff. burlingtonensis
Productus aff. concentricus
Spirifer aff. striatus
Reticularia? sp.
Griffithides? sp.
Bairdia? sp.

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* Collier, A. J., Geology and Coal Resources of the Cape Lisburne Region, Alaska, Bull. U. S. Geol. Survey No. 278, p. 22, 1906.

*Lot 14 D^1.**

Lithostrotion sp. A.
" sp. C.
Zaphrentis sp.
Pentremites? sp.
Fenestella sp.
Polypora sp.
Hemitrypa sp.
Cystodictya? sp.
Productus aff. setiger
" " *vittatus*
" " *cestriensis*
" " *burlingtonensis*
" " *pileiformis*
" sp.
Rhipidomella? sp.
Derbya? sp.
Camarotœchia sp.
" "
Rynchopora sp.
Dielasma? sp.
" ? sp.
" *turgidum?*
Spirifer aff. neglectus
" " *subcardiiformis*
" " *agelaius*
" " *rostellatus*
Martinia? sp.
Spiriferina aff. subelliptica
Athyris aff. incrassata
Clothyridina hirsuta?
" *roissyi*
Eumetria marcyi?
" *?* n. sp.
Hustedia? n. sp.
Platyceras sp.
Griffithides? sp.

While some of the collections are much less numerous than others, it is probably safe to refer them to a single fauna, which is without much question of lower Carboniferous or Mississippian age. It is true that some of the forms appear to be allied to species in the Burlington and Keokuk of the Mississippian section, but I believe that the beds furnishing these fossils should correlate only with the upper Mississippian. Indeed, the faunas are especially suggestive of the well-known fauna of Spergen Hill, which is known to have been rather extensively distributed toward the northwest.

I have long been of the opinion that our upper Mississippian correlates in a general way with the Mississippian limestone of

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* D^1 represents the uppermost 100′ of division *d* of the section.

Europe and Asia, but the evidence has been more or less indirect and general in character. The present faunas are especially interesting, because they seem to show to some extent a mingling of the two faunas. The Mountain limestone element is represented by the abundance of *Lithostrotion*, and other features could probably be pointed out by one familiar with the European faunas. The coral fauna of the Mountain limestone is already known in Alaska, especially at Cape Lisburne, but it has not there so far as known the admixture of Mississippian types."

In connection with the interesting resemblance of the Cape Thompson fauna to the Spergen Hill fauna pointed out by Dr. Girty, reference may be made to the minute character of many of the brachiopods occurring at horizon 14 D^1. In this feature the fauna strikingly resembles the depauperate Spergen Hill fauna. The presence in the fauna of a small specimen of *Pentremites* or a closely allied genus is also worthy of note in this connection. Although extremely abundant in the Mississippi valley, this blastoid has been recognized at but two localities in the Rocky Mountains, and in both of these occurrences it is associated with a fauna closely resembling the Spergen Hill fauna.

The higher beds of the Cape Thompson section are brought in contact with the beds already described in the midst of a zone of rather local but complicated folding and possibly of faulting, which renders it impossible to give even an approximate estimate of their thickness as seen from the top of the southeastern portion of the Cape Thompson cliffs; but between the second and the fourth deep ravines separating the high ridges just southeast of the cape along the coast the exposures are continuous for two miles, exposing a section of northerly dipping beds in which the dip decreases from 35° to 0 near the middle of the synclinal. We find in the series of cliffs which face the sea to the southeast of the second ravine below Cape Thompson a section which passes without structural complications from the fossiliferous Carboniferous limestones to the top of the highest beds exposed in this vicinity. This section is as follows;

Section 15, two miles southeast of Cape Thompson.

e	Soft black shales	500 +
d	Dark cherts and thin-bedded cherty limestones with some greenish bands	25′
c	Argillites with bands of black, green and dull red cherts	600′
b	Light gray limestone weathering buff, with some bands of dark chert. Apparently barren of fossils	2000′ + —
a	Light gray limestone similar to the above, but with less chert and containing numerous fossils in which corals are conspicuous	3000′ +

In the upper part of the lowest division of this thick limestone series, *a* of the section, fossils are fairly abundant, and represent about the same species as found at 14 D'. Only a few were collected, however. These are given in the following list by Dr. Girty, whose remarks on the general faunal relations of these faunas have already been given.

Lot 15 A.

Zaphrentis sp.
Spirifer aff. striatus
Composita ? sp.

The close physical resemblance of the second division (*b*) of the limestone series to the lower leaves little doubt that it is also of Carboniferous age. It may represent the Upper Carboniferous, which has not been recognized anywhere on the northwestern coast of Alaska, though known on the Yukon and in southeastern Alaska.

The lithologic change at the top of this limestone series is abrupt. The beds included in *c* and *d* are essentially similar, and represent the same formation, although there is less of the calcareous element in the lower beds. Fossils were found, however, only in the upper beds marked *d* in the section. They occur in great abundance in certain strata in this portion of the section. About seven feet near the top are composed almost exclusively of shells which have been largely altered to chert. Dr. T. W. Stanton has furnished the following report on the fossils secured from this horizon :

" Lot 15*d*. Mouth of creek 2 miles southeast of Cape Thompson.

This collection consists of limestone fragments with numerous specimens of aviculoid shells referable to *Pseudomonotis subcircularis* (Gabb) or to a closely related species. No other recognizable species are associated with it. This species occurs in an Upper Triassic horizon in California, and it has been accepted as sufficient evidence for the Triassic age of rocks containing it at Cold Bay and in the Copper River region of Alaska. In my opinion, the horizon which yielded it at Cape Thompson is also Upper Triassic.

Among the collections obtained by Mr. Collier in the Cape Lisburne region some years ago there are several small lots consisting mainly of a form that seems to be identical with *Pseudomonotis subcircularis* and probably comes from about the same horizon as this Cape Thompson locality. These fossils were at that time identified as Aviculopecten and referred to the Carboniferous, chiefly because of the stratigraphic relations they were supposed to hold with well-characterized, Carboniferous faunas. If Mr. Kindle's interpretation of the structure is correct the horizon in question at Cape Thompson is above all the Carboniferous faunas and offers no stratigraphic difficulties in its reference to the Triassic."

The fossils in Collier's collection alluded to above as having been included in the Carboniferous fauna appear in the lists published by him as faunules composed exclusively of lamellibranchs and with one exception showing no associated species which would point definitely to their Carboniferous age. This exception is the faunule of station 4 A C 16,* and it includes in addition to *Aviculopecten ?* sp., *Productella* sp., *Reticularia* sp., *Prœtus* sp., etc. Examination of these fossils shows that the *Aviculopecten* of this faunule is an entirely different shell from the "Aviculopectens" of the other faunules, which contain only "*Aviculopectens.*" It does not, therefore, connect the faunules composed almost exclusively of the latter with an undoubted Carboniferous fauna, as Messrs. Collier and Washburne, who collected the fossils, supposed it did. With reference to the stratigraphic evidence of the superposition of Carboniferous limestone above the beds containing "*Aviculopecten*" (*Pseudomonotis subcircularis*) in the Cape Lisburne region, it may be remarked that the region is one in which faulting is a common and characteristic feature, and one, therefore, in which present superposition might not represent the original relations of the beds.

The beds containing *Pseudomonotis subcircularis* at Cape Thompson and the 500 feet or more of soft shales above them lie nearly horizontal for about half a mile to the south of the anticlinal arch known as Agate Rock. The belt of territory underlaid by these softer horizontal beds is a valley region broken up by ravines and bordered on each side by an elevated limestone ridge and moderate-sized hills. If the shales were followed by any thick limestone formation, its presence should be manifested in the topography, but there is no such evidence of any limestone series above the flat-lying shales. The soft, black shale comprising the highest subdivision of this section contained no fossils where examined by the writer, and we are without definite evidence as to whether it should be assigned to the Triassic or Jurassic. The resemblance of the carbonaceous shales comprising it to portions of the Corwin formation as described by Collier† near Cape Lisburne suggests its provisional correlation with that formation.

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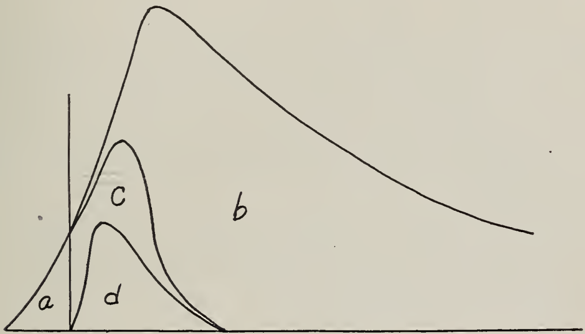
* Bull. U. S. Geol. Survey, No. 278, p. 23, 1906.

† Collier, A. J., Geology and Coal Resources of the Cape Lisburne Region, Alaska, Bull. U. S. Geol. Survey, No. 278, pp. 27–28, 1906.

Art. XLIX.—*A New Method of Measuring Light Efficiency;* by C. C. Hutchins.

The measurement of light efficiency has been attended with unusual difficulties considering that what is required is merely the ratio of two numbers representing respectively the values of the visible and total radiation of the source. Nor do the difficulties arise merely from the necessity of comparing large things with small, but rather for the want of some method of properly separating the quantities to be compared.

To obtain a complete energy curve, and to compare the integral of the visible portion with the total is an extremely tedious and somewhat uncertain procedure. Ångström's method requires an elaborate apparatus and the application of several troublesome corrections.



It is believed that the following method will be found as accurate, and much more simple and direct than those hitherto in use.

Theoretical.—Let the figure represent the energy curve of the light source; the vertical line separating the visible (a), from the infra red (b). If now we define efficiency as the ratio of the visible to the total radiation, we have:

$$\text{efficiency} = \frac{a}{a+b}.$$

Let now a water cell a few millimeters thick be placed in the path of the light. Assuming for the moment that the water is perfectly transparent to light; $a+c$ becomes the transmitted energy, the curve coming down to zero at wave length $1{\cdot}8\mu$.

Further let a cell identical with the water cell, but containing a water solution opaque to light but transmitting more or less infra red, be interposed: and let the transmitted energy be d. The transmission curve d must lie within the same narrow limits with c and the two areas be strictly comparable under like conditions.

If now we can measure $a+b$, $a+c$, d, and the ratio of c to d we have all that is required. For let

$$a + b = n$$
$$a + c = m$$
$$\frac{c}{d} = r$$

then

$$\frac{a}{a+b} = \frac{m-dr}{n}$$

Apparatus and Methods.—A thermopile consisting of a single junction at the focus of a small concave mirror set in a proper tube with diaphragms is pointed at the light and exposure made by moving a double wooden shutter. The deflection of the galvanometer is reduced by a known amount by putting resistance in the circuit. The deflection so obtained is proportional to n.

A water cell about 5^{mm} thick, having thin plate-glass walls, is then placed behind the shutter; the resistance is removed from the circuit, exposures made as before, and we obtain deflections proportional to m.

For obtaining d, a preliminary study of a large number of substances showed potassium permanganate to be quite suitable. It is very strong in color in solution, may be made opaque to sunlight in a thin layer, while transmitting a considerable amount of infra red. A duplicate of the water cell is filled with a solution of permanganate of such strength as to just show the light under investigation, when held between the light and the eye.

This cell being substituted for the water cell, we obtain a deflection proportional to d.

To find the ratio r.

A spectroscope was given the following additions. A long slit was put in the place of the ordinary short one. The eyepiece was removed and replaced by an ebonite screen having a rectangular opening. One edge of the opening was cut to fit the curve of the spectrum lines in the red. The spectrum of the light source is focused upon the screen and the telescope adjusted so that the visible spectrum is just cut off by the curved edge. The infra red alone now appears in the opening. In this position the telescope is firmly clamped.

Over the eye end of the telescope is now slipped a tube, having at its farther end a concave mirror and thermal junction. The mirror is large enough to receive the entire cone of rays coming through the screen, and condenses them upon the junction at its focus. This arrangement was used because it was at hand; a thermopile or bolometer, having a suitable receiving surface, placed immediately behind the screen, would be simpler. An image of the light source being thrown upon the slit of the spectroscope, the water and permanganate cells are placed alternately against the objective of the collimator; a shutter is moved as before, and the attached galvanometer gives deflections proportional to c and d respectively.

Remarks upon setting the screen.—It has been customary in determinations of light efficiency to assume some definite limit to the visible spectrum, as $\cdot 76\ \mu$. Such a limit is quite useful for purposes of uniformity, that one man's work may be compared with another's, but only roughly corresponds to fact except in the case of sunlight. The limit of the spectrum is not the same for all lights or all eyes. It would therefore seem more logical to set the screen upon or near the limit of the red of the light under examination, although this will commonly give a smaller value for the efficiency than that obtained from $\cdot 76\ \mu$ as a limit. This procedure seems further justified when we observe how steeply the energy curve rises at the limit of the red; so that a very slight movement of the screen upwards in the spectrum diminishes the apparent efficiency largely, while the actual light is diminished by an inappreciable amount. The smaller values therefore more nearly represent the practical efficiencies.

Example of the method.—The following measurements were made upon a portable acetylene lamp in which the gas is generated by automatically feeding granular carbide into water contained in the base of the lamp. The feed being intermittent, the light varies considerably but a fair average could be obtained by distributing the readings over a considerable time.

The resistance of the galvanometer and circuit is 2·203 ohms.

Through water the mean of 5 deflections was 202·2 millimeter divisions. Through permanganate 45·0 divisions. Ten ohms were added to the circuit, and the lamp direct gave 230·6 div., which when reduced to the scale of the others becomes 2531.

With the prismatic apparatus the mean of 20 readings through water with 4 ohms in circuit was 293·7. The resistance of the circuit is 2·203, and the deflection without added resistance reduces to 827·0.

The mean deflection through the permanganate cell was 205·8.

From these readings we have

$$\begin{array}{ll} m = 202{\cdot}2 & dr = 180{\cdot}9 \\ n = 2531{\cdot} & m - dr = 39{\cdot}3 \\ d = 45{\cdot}00 & \dfrac{m - dr}{n} = {\cdot}0263 \\ r = 4{\cdot}028 & \end{array}$$

This result is subject to a plus correction of 13 per cent because of the loss of light to that amount in passing through the water cell. Applying this correction, we get ·0296 for the light efficiency.

A second determination made after resetting the screen and changing the sensibility of the galvanomter gave ·0323. The mean of the two is ·0309 and the departure from the mean 6 per cent. The result may be considered very satisfactory considering the large change in apparent efficiency produced by a small displacement of the screen.

Nichols and Coblentz* found ·033 from integration of the energy curve of a cylindrical acetylene flame, and ·030 from a comparison of the transmission curve through water and iodine in bisulphide of carbon.

Bowdoin College, Oct. 30, 1909.

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* Physical Review, Oct. 1903.

Art. L.—*Three New Fossil Insects from Florissant, Colorado;*[*] by S. A. Rohwer, Boulder, Col.

Raphidia mortua n. sp.

Sex doubtful: length of the anterior wing, 10^{mm}; width of the anterior wing, 3^{mm}; length of the meso- and metathorax and abdomen about 8^{mm}. Color brown, the thorax darker, legs except one tibia, which is pale, wanting; the head and prothorax are wanting. The venation is pale brown. Costal area large, with six cross-veins. Subcosta straight, joining the costa at about the length of the stigma from the stigma. The area between the subcosta and the radius crossed by at least one distinct cross-vein; this cross-vein is not interstitial with any of the cross-veins of the costal area, and would form an obtuse angle with them. Stigma at the base perpendicular, about equal in width throughout, crossed by an oblique vein; the vein at the apex is curved basally so that the end of the stigma is concave. The first cell below the stigma extends beyond the cross-vein of the stigma, but does not extend beyond the apex of the stigma. The cell below this is as in *Raphidia oblita.* The terminal veinlets form six V-shaped cells. The hind wings are about the same length as the fore wings. Besides the usual differences the stigma is broader where the cross-vein joins it, and there are only three V-shaped marginal cells. The following measurements of the fore-wings are in micromillimeters:

Distance of the cross-vein from the apex of the stigma on the costa	935
Distance of the cross-vein from the base of the stigma on the costa	850
Distance of the cross-vein from the apex of the stigma on the radius	765
Distance of the cross-vein from the base of the stigma on the radius	425
Distance of the apex of the stigma from the apex of the cell below it	306
Distance from the base of the stigma to the subcosta	850
Length of the cross-vein of the cell between the subcosta and the radius	277

The venation of this species is very different from that of *Raphidia notata* (fig. 2, Pl. 5, Lief. I, Fossilen Insekten), which has the subcosta joining the costa at the base of the stigma.

If compared with the venation of *Raphidia oblita* as figured by J. F. McClendon in the Ent. News, xvii, April, 1906, p. 117,

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[*] Thanks are due to Prof. T. D. A. Cockerell for the pleasure of studying these interesting fossils, and for going over my manuscript.

the following differences will be noted: The subcosta is at a greater distance from the stigma. The apex of the stigma is concave. There are fewer cross-veins in the costal area. The cross-vein between the subcosta and the radius is not interstitial with a cross-vein of the costal area. The cells below the stigma are shorter. The cell bounded above and below by R$_1$ and R$_5$ (= RS) is pentagonal not hexagonal.

Of all the fossil species it seems nearest to *Inocellia tumulata* Scudder, but it differs from that species in having a cross-vein in the stigma; the cell below the stigma reaches beyond the middle of the stigma; the space between the subcosta and the costa is transversed by a number of cross-veins.

Habitat: The Tertiary shales of Florissant, Colorado, collected in 1908 by George N. Rohwer at Station 14. Type in the collection of the University of Colorado.

The following table of the fore wings of certain species, both fossil and recent (the recent ones are starred), is interesting in that it shows the relation of the fossil and recent faunæ; and useful in that it separates the species of fossil *Raphidia* found at Florissant. As Dr. Scudder has given a table of the species of *Inocellia* they are not included.

Subcosta joining the costa at the base of the stigma .... *notata**
Subcosta joining the costa remote from the stigma ... 1
1. Stigma without a cross-vein .... *Inocellia*
   Stigma with at least one cross-vein 2
2. R$_1$ with but one branch beyond the stigma 3
   R$_1$ with two branches beyond the stigma 6
3. The costal area very small and apparently without cross-veins; the subcosta forming most of the margin of the wing; stigma "small, semi-oval" *R.* (?) *tranquilla*
   The costal area not small and with distinct cross-veins 4
4. The first cell below the stigma not extending beyond the stigma *R. mortua*
   The first cell below the stigma extending beyond it 5
5. The cell bounded by R$_1$ and R$_5$ (= RS) pentagonal *R. rhodopica**
   The above mentioned cell hexagonal .... *R. oblita**
6. R$_3$ not forked; length of the anterior wing 12^{mm} *R. exhumata*
   R$_3$ forked; the anterior wing 14^{mm} .. *Megaraphidia elegans* [†]

Chrysis miocenica n. sp.

Female: length of the thorax, 6^{mm}; length of the head, 2^{mm}; length of the abdomen, 8^{mm}; length of the anterior wing, 7·5^{mm},

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[†] For further differences between *R. exhumata* and *M. elegans* see Bull. Am. Mus. Nat. Hist., 1909, p. 73. In the figure of *M. elegans* (Bull. Am. Mus. Nat. Hist., 1907, p. 607) the artist has omitted the costal area, and has drawn R$_1$ incorrectly, with one instead of two branches beyond the pterostigma. The cross-vein below the stigma is too far from the end of the latter.—T. D. A. C.

The head is not longer than the thorax. The malar space is distinct; the eyes oval. The flagellum is about two and a half times as long as the scape; the first joint of the flagellum is distinctly longer than the second and the second is a little longer than the third. The legs are rather more robust than usual. The venation is rather weak, and normal, differing from *C.* (Gonochrysis) *densa* Cresson only in that the radius rises nearer the middle of the small stigma. The abdomen is as long as the head and thorax combined. The apical teeth cannot be seen, but from the general appearance the insect suggests *Gonochrysis.* The ovipositor is exserted, and is rather more robust than usual, length 2·75^{mm}. In the specimen the sculpture cannot be seen, but it is undoubtedly punctured as in the recent species of to-day.

Habitat: The Tertiary shales of Florissant, Colorado, at Station 14. The collector is unknown. The type is in the University of Colorado.

The only other fossil *Chrysis* from Florissant is *C. rohweri* Ckll., which differs from the present species in its much smaller size, and the abdomen is shorter than the head and thorax. *Chrysis mortua* is in general appearance like the recent species *densa* Cress. found at Florissant to-day. It is however much larger than any specimen of *densa* known to me.

Philanthus saxigenus n. sp.

Sex doubtful; length of the head and thorax and first two abdominal segments, 9·5^{mm}; length of the anterior wing, 8·75^{mm}. Head about the same width as the thorax; ocelli in a low triangle; the lateral ocellus about 204μ in diameter. Thorax subquadrate, 4·5^{mm} long, and at the wings 4·5^{mm} wide. The head and thorax finely sculptured; the mesonotum with two slightly converging grooves near the center; these grooves extend posteriorly to about the hind wings; a little above the tegulæ are two shorter grooves; the tegulæ are rather large. The hind tibiæ are short yet not shorter than in some of the recent members of the genus: they are not serrate or spinose in the fossil; the spurs are shorter than the hind basitarsus; the four anterior legs are not present in the fossil. The radial cell is normal (attaining the costa without an appendiculation); the stigma is of medium size; third transverse cubitus is strongly bent basally about the middle; the second recurrent nervure is interstitial with the second transverse cubitus; the second transverse cubitus is slightly oblique; the first recurrent nervure joining the second cubital cell about the middle; the transverse median received by the discoidal cell distinctly beyond the median. Abdomen sessile; the first segment widening toward the apex; abdomen beyond the second segment wanting. Color perhaps rufous, no black markings evident in the specimen. Wings hyaline, the venation pale brown. The following measurements are in micromillimeters :—

Length of the stigma	850
Length of the second tran. cubitus	476
Breadth of the stigma	170
Length of the third cubital cell on the radius	1820
Length of the second cubital cell on the radius	935
Length of the first cubital cell on the radius	255
Length of the second cubital cell on the cubitus	1105
Length of the first cubital cell on the cubitus	1530
Distance the tran. median is beyond the basal	289
The first recurrent nervure beyond first tran. cubitus	325

Habitat :—Tertiary shales of Florissant, Colorado. One specimen collected by Prof. T. D. A. Cockerell at Station 9 (a hill facing north about three-fourths of a mile southwest of the town). The type in the University of Colorado. Many thanks are due to Prof. Cockerell for assistance in the study of this interesting fossil. This species is very distinct from *Prophilanthus destructus* Ckll., the only other fossil Philanthid known from Florissant, being readily distinguished by its smaller size and the radial cell reaching the costa. In the position of the second recurrent nervure *P. saxigenus* departs from all other species of the genus *Philanthus* known to me, but this is a matter of small importance. The grooves of the mesonotum are very similar to those of *Aphilanthops fridigus* (Cress.), but it cannot be an *Aphilanthops* on account of the shape of the radial cell. *Philanthus pulcher* D. T. (*pulchellus* Cress.), which has been taken at Florissant, is much like *P. saxigenus*, but it is smaller and the venation is different. *Philanthus sanborni* Cress. (Mass.) is very similar in general habitus to *saxigenus*, and the specimen before me has the second recurrent nearer to the second transverse cubitus than in any other species I have seen. The relative length of the second and third cubital cells is not reliable, and I do not think the genus *Epiphilanthus* is a valid one. It might be used as a group ; if so *P. saxigenus* should be placed in the group so formed.

ART. LI.—*On Connellite and Chalcophyllite from Bisbee, Arizona;* by C. PALACHE and H. E. MERWIN.

THE following note is based on a single specimen of connellite sent to the Harvard Mineralogical Laboratory for identification by Mr. W. B. Gohring. This one piece, all that was found, came from the Calumet and Arizona mine at Bisbee, and was generously placed at our disposal by Mr. Gohring.

The specimen is a flat fragment about an inch square consisting largely of connellite in groups of radiating needles of characteristic dark blue color. On one side it is incrusted with cuprite and dark green melanochalcite. On breaking it apart a small cavity was exposed, in which were a few terminated needles of connellite, several cubical crystals of cuprite, and several dark green flat crystals of chalcophyllite, mistaken at first for spangolite.

The needles of connellite are deeply striated lengthwise, but could be adjusted accurately on the two-circle goniometer notwithstanding, and gave fair readings for the terminal planes. These seem to be confined to faces of the unit pyramid; both first and second order prisms are apparently present. The largest crystal measured was about 0·5^{mm} in diameter; the average needle was much more slender, however.

The average of nine values (on two crystals) for the angle $0001 \wedge 10\bar{1}1$ was 53° 50′ corresponding to an axial ratio $a : c = 1 : 1{\cdot}185$. This value is much nearer to that of Story-Maskelyne, $a : c = 1{\cdot}156$ than to the ratio deduced from Penfield's measurement of the pyramid angle, $a : c = 1{\cdot}339$; it is probably based on better measurements than either.

The needles of connellite show no cleavage. The specific gravity is 3·396, determined by suspension in barium-mercuric iodide (Merwin).

Optical properties.—(Merwin). Uniaxial, positive. Refractive indices : $\omega = 1{\cdot}724$; $\epsilon = 1{\cdot}746$; determined under the microscope by bringing mixtures of monobromonaphthalene and sulphur dissolved in methylene iodide to match the indices of refraction as nearly as could be done by observing the Becke effect: the refraction of the liquids was then found by means of the reflectometer. The color is a clear, deep, slightly greenish blue even in microscopic fragments.

The birefringence was determined independently of the refractive indices by the following method: Various-sized minute prisms of the mineral placed between crossed nicols under the microscope showed only three distinct colors, blue, purple and green. In case blue appeared the interference color was, of course, blue, and in case purple appeared the interference color was red. From either of these colors the difference of retardation of the two refracted rays could be closely estimated. But when green was the color assumed, the interference color might have been either orange, yellow or green. In this case the one-quarter undulation mica plate was inserted so as to raise or lower the color a sufficient amount to produce either blue or purple. Then by making proper allowance for the mica plate the interference color was calculated. By measuring the thickness of the prism the birefringence of the mineral was calculated from the interference color and found to be ·021. This figure, the mean of seven observations, is as likely to be correct as the one derived from the refraction indices, ·022.

Chemical composition—(Merwin). Material sufficient for chemical analysis (0·73 gram) of ideal purity was easily obtained by hand-picking. The analysis is compared below with the only other one we have, that of Penfield made on ·074 gram, and leads to a somewhat different formula. The water was given off in three distinct fractions at about 235°, 260° and incipient redness. A little of the second fraction of water was seen to come off before the heat was removed in estimating the first fraction.

	Connellite, Merwin	Molecular Ratios			Connellite, Penfield		
SO_3	3·43	·043	·98	1	4·9	·061	1·
Cl	6·37	·18	4·09	4	7·4	·209	3·4
CuO	75·96	·959	21·84	22	72·3	·913	15
H_2O below 220°	·25	——			·4		
H_2O, 220°–260°	12·06	·61	15·24	20	16·8	·933	15·3
H_2O, 260°–300°	2·10	·117	2·65				
H_2O above 300°	1·66	·092	2·11				
	101·83				101·8		
Less O=Cl	1·42				1·67		
Total	100·41				100·13		

As shown by the molecular ratios, the composition of this connellite may be expressed by the empirical formula $Cu_{22}Cl_4SO_{23} + 20H_2O$. The corresponding formula for Penfield's analysis is $Cu_{15}(Cl.OH)_4SO_{16}+15H_2O$.

The distribution of the water might be accounted for by supposing some such molecular grouping as this:

$$[CuSO_4.3Cu(OH)_2.H_2O].2[CuCl_2.Cu(OH)_2].14[Cu(OH)_2].$$

The first part of this formula is identical with that of the mineral langite, which loses one equivalent of water at a moderate temperature. The fact that when first heated connellite yields water alone indicates the presence of a copper hydrate molecule easily decomposed by heat; thus the fifteen equivalents of water first given off are accounted for in our formula: cupreous chloride volatilizes at a higher temperature, and finally chlorine and sulphur trioxide are expelled.

Penfield's analysis of connellite from Cornwall may be represented by a molecular grouping of the same general form as the above, but quite different in its proportions:

$$[CuSO_4.3Cu(OH)_2.H_2O].2[CuCl_2.Cu(OH)_2.H_2O].7[Cu(OH)_2].$$

Chalcophyllite was identified in the specimen by measurement of crystals, and by qualitative chemical tests for arsenic, copper and aluminum. Most of the crystals were irregular plates embedded in the connellite. The perfect basal cleavage and rich green color were conspicuous features. A single minute implanted crystal was obtained, which gave extremely satisfactory readings for the forms $c\,(0001)$, $x\,(10\bar{1}4)$, $e\,(01\bar{1}2)$, $r\,(10\bar{1}1)$, and $y\,(02\bar{2}1)$. Of these forms x is new, and y does not appear in Dana's list, although given by Goldschmidt (Winkeltabellen). The measured angles differ considerably from those derived from Des Cloizeaux's element (crystals from Cornwall), and a new ratio was therefore calculated, as shown below:

$a : c = 1 : 2{\cdot}554 \qquad p_0 = 1{\cdot}702$ Des Cloizeaux.
$a : c = 1 : 2{\cdot}671 \qquad p_0 = 1{\cdot}780$ Palache.

	Calculated			
	Des Cloizeaux	Palache	Measured	No. of faces
Angle $c \wedge w$	26°10′	27°12′	——	—
$c \wedge x$	——	37 38	37°41′	3
$c \wedge d$	44 30	45 08	——	—
$c \wedge e$	55 51	57 02	56 59	3
$c \wedge r$	71 16	72 02	72 02	3
$c \wedge y$	——	80 48	81 01	2

The measured crystal is of rhombohedral habit with the unit form dominant and very small base.

As this mineral was first mistaken for spangolite, it seems worth while to note here the close similarity in physical characters existing between the two. Both are soft, dark green, hexagonal with perfect basal cleavage, and optically negative. Furthermore, the chalcophyllite rhombohedrons have inclinations to the base which are closely matched by pyramids occurring on spangolite.

Unfortunately there was not enough of this material for quantitative analysis, which would have been desirable in view of the uncertainty as to the composition of chalcophyllite.

Considerable interest attaches to the occurrence of these minerals at Bisbee, because of their association elsewhere with spangolite. It will be recalled that the type specimen of spangolite came from an unknown locality in southern Arizona. With it were minute blue prismatic crystals, not determined by Penfield, but suggesting connellite. While spangolite has not yet been found at Bisbee, it now seems highly probable that the original specimen came from there, and that it may be rediscovered if carefully sought for.

Mineralogical Laboratory,
Harvard University, July, 1909.

Art. LII.—*On the Optical Properties of Hastingsite from Dungannon, Hastings County, Ontario;* by R. P. D. Graham.

In a paper which appeared in this Journal for July, 1894, the discovery of a large area of nepheline syenite in the township of Dungannon, in the Province of Ontario, was announced and the geological relations and mineralogical characters of the mass were briefly described. Further exploration showed that the nepheline syenites in this part of Ontario had a very wide distribution and the results of a detailed study of them has just appeared.* In the township of Dungannon, about two miles east of the village of Bancroft, the nepheline syenite contains a remarkable hornblende associated with a titaniferous andradite; these minerals were analyzed by Dr. Harrington and their chemical composition was discussed in a paper which appeared in this Journal in March, 1896.† No thorough examination of the optical properties of the remarkable hornblende, however, has hitherto been made, and the writer, at the request of Dr. Adams, has studied the mineral with a view to the determination of its optical characters.

The material employed was that obtained by Dr. Adams at the original locality above mentioned.

The hornblende is distributed throughout the rock in fairly large amount as small black individuals or aggregates with a high luster, especially on the cleavages; but no fragments having crystal faces were found on the specimen examined. Except in very thin flakes, it is practically opaque.

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* The Nepheline and Associated Alkali Syenites of Eastern Ontario, by Frank D. Adams and Alfred E. Barlow; Trans. Royal Society of Canada, 1908–09.

† On a new Alkali Hornblende and a titaniferous Andradite from the Nepheline Syenite of Dungannon, Hastings Co., Ontario, by Frank D. Adams and B. J. Harrington.

Under the microscope in parallel light, thin sections appear quite fresh and greenish in color, with a very strong pleochroism. Those rhomb-shaped sections, which are cut more or less perpendicular to the prism, and show the two sets of cleavage cracks intersecting at about 56°, are yellowish green for light vibrating along the shorter diagonal of the rhomb, and deep bluish green, or nearly opaque if the section is at all thick, for light vibrating parallel to the longer diagonal. Prismatic sections are also very strongly pleochroic, appearing deep bluish green to opaque when the light traversing them vibrates along the cleavage and pale yellowish green for light vibrating perpendicular thereto. Between crossed nicols the latter have various angles of extinction with the cleavage cracks, the maximum value observed being about 30°.

Some fragments, however, while being distinctly pleochroic, exhibit this property in a comparatively slight degree, and these are further found to be almost isotropic between crossed nicols. When examined in convergent light, a dark cross, somewhat blurred and thickened at its center, is seen, and it was this unusual feature which first drew special attention to the mineral. The cross does not separate into very definite hyperbolas on rotating the section, owing to its ill-defined character, but that the mineral is not truly uniaxial is evident from the pleochroism of these sections and also from the unsymmetrical manner in which the brushes are colored.

In the paper referred to above, it was stated that the axial angle is over 30° and possibly as much as 45°, the optic axes lying in the plane of symmetry, with a strong dispersion in the sense $\rho > v$.

The optical determination of the mineral in the ordinary rock sections is a somewhat difficult matter, owing to the fact that even the thinnest slices, when cut normal to the acute bisectrix, have a very deep bluish green color, causing the whole field to be dark, while the power of the objective under which it can be examined is also necessarily limited in such cases. In the present instance, small chips of the mineral were crushed very finely under oil and examined under a 1/12″ oil immersion objective. The majority of the fragments were minute cleavage flakes, with a high extinction angle, the mean observed value being 22°, and they exhibit the strong pleochroism noted above for prismatic sections. The birefringence is low, compensation taking place when the quartz wedge is inserted across the prism. The dark brush which crosses the field on rotating the section (or the nicols) in convergent light is broadly fringed with red on one side and blue on the other, indicating a strong dispersion.

But there are always a few fragments lying on a plane which is approximately normal to the acute bisectrix and when these are sufficiently thin they exhibit a fairly well-defined optical figure. As had been previously noted, the central part of the interference figure, even when in the diagonal position, is not well illuminated, owing to the deep color and the weak double refraction of the mineral. The quasi-uniaxial figure is colored red in one pair of opposite quadrants, transverse to the cleavage cracks, and bluish green in the other, and it is usually difficult to decide as to which of these directions is the line joining the optic axes. If the axial plane lies in the plane of symmetry, as is usual in hornblende, then the angle for red is greater than that for blue, or $\rho > v$. But when exceedingly thin and less highly colored chips are examined, it is found that the hyperbolas open out *across* and not along the plane of symmetry. They are colored red on their concave side, and although the brushes are thick and frayed, a certain amount of bluish green light gets through in the narrow space which separates them, and the same color tints the rest of the figure. It was at first thought that this effect might be only an illusion and due to the fact that more light is transmitted near the red portions of the figure than elsewhere, thus causing an apparent opening of the hyperbolas in this direction. But the phenomenon was observed in many cases so clearly as to admit of no doubt in the writer's mind that in hastingsite the axial plane, for green light at least, lies at right angles to the plane of symmetry of the mineral; the axial angle for red light is less, and there may even be a crossing of the optic axial plane for these colors, since the interference figure observed in yellow light approaches more nearly to the uniaxial cross, although it is very ill-defined owing to the poor illumination of the field. The birefringence is weak and negative. Although the pleochroism of sections cut in this direction is comparatively slight, it is in the same sense as that noted above for those parallel to the prism.

Considered with reference to the crystallographic axes, the pleochroism is like that usually met with in amphiboles; but since in the case of hastingsite the plane of the optic axes lies across the plane of symmetry instead of along it, we have $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$, $\mathfrak{b}$ and $\mathfrak{c}$ being nearly equal.

It is impossible to make any accurate measurement of the optic axial angle, but it is evidently quite small. It was thought that it might be useful to make a rough estimate of its value by comparison with some other mineral of small angle, and biotite was selected for this purpose. A cleavage flake, in which the hyperbolas separated to about the same extent, so far as could be judged by the eye, as in the case of hastingsite, when examined under similar conditions, was found to have an axial angle, $2V = 17° 12'$; and allowing for the difference in refractive index between the two minerals, this would give for hastingsite, $2V = 16°$. From the nature of the method employed in arriving at this value, it can at the best be considered only as an extremely rough approximation; but it serves to indicate the probable order of the axial angle, which is much smaller than at first suggested.

The mean refractive index was determined by Schroeder van der Kolk's method, using thin cleavage fragments placed in the position of least absorption, i. e., for light vibrating across the prism. The liquids employed were methylene iodide and naphthalene monobromide, which mix to form a clear solution. The refractive index of the resulting mixture, after adjusting as nearly as possible to that of the mineral, was determined in the usual manner by means of a hand refractometer. The mean of several determinations gave 1·69 as the index of refraction of the mineral for light traversing it in this direction.

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Art. LIII.—*The Electrolytic Determination of Chlorine in Hydrochloric Acid with the Use of the Silver Anode;* by F. A. Gooch and H. L. Read.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccv.]

In Vortmann's work* upon the electrolytic determination of the halogens with the use of a silver anode, the determination of iodine in iodides was demonstrated experimentally; and the statement was made, with the promise of future demonstration, that chlorides and bromides are susceptible of similar treatment. It was shown that when a suitable electric current is passed through a solution containing a moderate amount of potassium iodide and a proper amount of sodium hydroxide, iodine may be fixed upon the silver anode while potassium hydroxide is formed at the platinum cathode. It was found that the addition of an alkali tartrate (3 grm. of Seignette salts) aided the fixation of the iodine as silver iodide upon the anode, but excepting the cases in which the amount of iodide handled was very small, good results were also obtained without the use of the tartrate. In this work, a disc of silver 5^{cm} in diameter was used as the anode and a similar disc of platinum, or a platinum dish, served as the cathode; the total volume of the solution was 100^{cm^3} to 150^{cm^3}, containing 6^{cm^3} to 10^{cm^3} of a 10 per cent solution of sodium hydroxide; and the current, less than ·07 ampere under a potential not exceeding 2 volts, was allowed to act for several hours. The end of the electrolysis was determined either by testing a few drops of the solution for iodine or by putting in fresh anodes until no more silver iodide was formed upon the anode surface. To determine the increase in weight of the anode due to fixation of iodine, the anode was removed from the liquid, washed with water and with alcohol, dried over a Bunsen flame, and finally heated to dull redness or to the fusing point of silver iodide for the purpose of removing oxygen also fixed upon the anode. It was noted that small amounts of silver (0·0010 grm. to 0·0015 grm.) were dissolved from the pure silver anode and deposited to some extent upon the platinum cathode; but to completely deposit upon the cathode the dissolved silver it is recommended to introduce a platinum anode after removing the silver anode and to pass the current for an hour. The sum of the increase in weights of both electrodes is the measure of the iodine fixed.

Vortmann thus emphasized strongly two points: viz., that the silver anode should be heated to a temperature sufficient to break away oxygen (held according to Vortmann in the

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* Monatshefte f. Chemie, 15, 280 (1894); 16, 674 (1895).

form of silver dioxide), and that account must be taken of silver dissolved from the anode. These are points which appear to have escaped the consideration of subsequent workers.

Speketer,[*] in the electrolytic separation of chlorine, bromine, and iodine under graded potential of current, dried the silver anode at 120°.

Smith[†] deposited the chlorine of the chlorides of sodium, barium and strontium upon an anode of silver gauze, the cathode being either platinum or mercury used as described by Myers.[‡] Upon passing the current the silver began to darken almost immediately from the lower edge upward, and when no further progress in the darkening was observed, it was assumed that the operation was at an end. The gauze was rinsed with water, alcohol, and ether, and was weighed after drying a short time. The alkali in solution was determined by titration with standard acid.

Withrow[§] determined similarly the iodine of potassium iodide and the chlorine of potassium chloride with the use of a spiral platinum cathode rotating at 300 to 500 revolutions per minute and a silver dish used as the anode. The deposit was dried in an air bath for weighing.

Hildebrand[‖] made use of an anode of silver gauze, either stationary or rotary, with either a simple mercury cathode or a mercury cathode arranged so that an amalgam of the liberated metal might be formed in an inner compartment and decomposed largely in an outer annular compartment. The gradual falling of the current to a minimum (0·005 to 0·02 amperes), determined by the formation of a small amount of alkali in the solution, indicated the advance of the process to completion. Hildebrand noted that after all the salt had been decomposed the weight of the silver anode might be indefinitely increased by the formation of silver oxide upon it, and, to avoid continuing the electrolysis after complete decomposition of the salt, adopted the plan of diluting the liquid when the current had apparently reached its minimum and stopping the current as soon as the fresh anode surface thus brought into action showed the formation of brown silver oxide. The gauze was removed, immersed in alcohol and then in ether, dried,[¶] and weighed. To secure the double advantage of making the anode deposits perfectly adherent and stirring the amalgam to secure complete decomposition in the outer compartment, rotation of the anode was tried, and the statement is made

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[*] Zeitschr. f. Electrochem., 4.

[†] Jour. Amer. Chem. Soc., xxv, 890 (1903).

[‡] Ibid., xxvi, 1124.

[§] Ibid., xxviii, 1350 (1906).

[‖] Ibid., xxix, 447 (1907).

[¶] Smith : Electro Analysis (1907), p. 305. "Dry the gauze over a steam radiator."

that when the rotating anode was used in the double cell nothing but pure water remained in the inner compartment after the salt under examination had been decomposed; that the falling of the current to 0·01 ampere or less indicated the end of the process; and that no harm could be done by running longer, as further increase in the weight of the anode was not possible. The results obtained by weighing the anode were concordant with one another, close to the theory, and in agreement with the figures obtained by titration of the alkali formed in the liquid.

McCutcheon,[*] Lukens and Smith,[†] and Lukens and McCutcheon,[‡] have studied still further the behavior of various chlorides, and other salts, in electrolysis with the use of the rotary silver anode and the mercury cathode.

Throughout all the later elaborate experimentation no reference is made to the points emphasized by Vortmann as necessary in the electrolytic determination of iodine, viz., the ignition of the silver anode to break away fixed oxygen and the determination of silver dissolved or carried to the cathode.

From a consideration of the apparently very exact results obtained in the treatment of various chlorides it would seem that nothing could be simpler than the accurate determination of chlorine in hydrochloric acid by similar means. That such is not the case, however, will be seen from the following account of experimentation upon the electrolytic determination of chlorine in hydrochloric acid with the use of the silver anode. In a preliminary experiment a large silver crucible was used as the anode with a smaller platinum cathode, and a current of 1·5 to 0·09 amperes under a potential of 3·5 to 4 volts passed for an hour through a solution containing originally 0·2184 grm. of hydrogen chloride. It was found in this experiment that the combined weights of anode, cathode, and suspended silver compound collected on asbestos failed by several milligrams to make up the weight of chlorine contained in the hydrogen chloride; and testing of the residue left after evaporation of the clear filtrate showed distinctly the presence of a chlorate.[§]

In another experiment, similar excepting that the voltage of the current was raised as the operation progressed, a current of 0·5 to 0·24 ampere under a potential of 4 to 80 volts was passed for thirty minutes through a solution containing at the outset 0·2184 grm. of hydrogen chloride. The combined

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[*] Jour. Amer. Chem. Soc., xxix, 1445.

[†] Ibid., xxix, 1455.

[‡] Ibid., xxix, 1460.

[§] The test for a chlorate was made by treating a portion of the residue with a saturated solution of manganous chloride in hydrochloric acid (Gooch and Gruener, this Journal, xliv, 118, 1892).

weights of the ignited anode, cathode, and suspended silver compound here also fell short of the weights of chlorine present by 0·0039 grm. In this case the suspended precipitate was brownish, and the clear filtrate deposited upon standing for forty-eight hours a precipitate which, when filtered off and treated with hydrochloric acid, and dried, weighed 0·0029 grm. On standing for a week the filtrate threw down another slight deposit. Silver oxide was plainly found at the anode, and the behavior of the clear filtrate is suggestive of the formation of silver hypochlorite and its subsequent transformation to insoluble silver chloride and silver chlorate.

In a third experiment, essentially similar to the first excepting the use of a platinum cathode, the formation of a deposit of silver upon the cathode was distinctly visible. It is plain, therefore, that the solution of silver from the anode, the deposition of the silver upon the cathode, the production of oxygen acids of chlorine (hypochlorous acid and chloric acid) and possibly their silver salts, are phenomena likely to occur in the electrolysis of hydrochloric acid with the use of the silver anode.

In subsequent experiments the rotating anode of the form used by Hildebrand,* consisting of two circular disks of platinum gauze of 300 meshes to the square centimeter, 5 centimeters in diameter and mounted 5 millimeters apart and parallel to one another upon a perpendicular wire of platinum used as the axis of revolution, was substituted for the stationary anode. This apparatus was plated with silver by rotating it as the cathode in a solution of potassium silver cyanide. After plating, it was prepared for use by careful washing, drying, and ignition to incipient redness in the tip of a Bunsen flame. A 200^{cm^3} platinum dish was used as the cathode. The pure hydrochloric acid employed was made up of approximately N/10 strength. It was standardized by precipitating with silver nitrate in the hot solution and weighing the silver chloride filtered after standing over night and chilling. Parallel determinations showed 0·4247 grm. and 0·4248 grm. of chlorine in 100^{cm^3}. The residue left by evaporation of 25^{cm^3} of the solution was found in parallel experiments, one at the beginning and the other at the end of work, to be 0·0001 grm. and 0·0003 grm.

In each experiment a portion of the standard acid, usually 25^{cm^3}, was drawn from a burette into the 200^{cm^3} platinum dish which served as the cathode. The dish with contents was adjusted, the anode set in the rotating apparatus, and the solution so diluted that the anode dipped well under the liquid while distant from the cathode by about 1^{cm}. The anode was

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* Jour. Amer. Chem. Soc., xxix, 450, 1907.

rotated at about 300 revolutions to the minute, and the current turned on. At the end of the time recorded the anode was removed from the liquid, washed carefully with alcohol and then with ether, dried carefully by slow agitation well above the Bunsen flame, and weighed; thereafter it was ignited to incipient redness at the top of the Bunsen flame and weighed again, this operation being repeated to insure a constant weight. In the ignition, the dark color of the anode, taken on in electrolysis and retained throughout the drying process, largely disappeared. It was determined experimentally that the anode and deposit dried in the manner described incurred no further loss of weight when heated in the air bath at 105°–110°; and a single ignition served to bring the anode and deposit to the second constant weight.

The liquid remaining after electrolysis was tested with litmus paper and then subjected to the further tests indicated in the accounts of individual experiments. The cathode was examined for deposited silver, and in some cases this was dissolved off the platinum in nitric acid, precipitated as silver chloride, and weighed. The details and results of the experiments are summarized in Table I.

In the experiments of Series A of the table, the apparent error in terms of chlorine, as determined from the weight of the carefully dried anode, varied from −0·0019 grm. to +0·0022 grm.; but it is to be noted that the dried anodes lost upon ignition amounts varying from 0·0030 grm. to 0·0070 grm., these losses being presumably due to the expulsion of oxygen fixed in the electrolysis. Obviously, the amount of chlorine fixed cannot be calculated from the weights of the dried anodes. If the weights of the ignited anodes be taken as the basis for the calculation of fixed chlorine, the errors of the chlorine determinations vary from −0·0026 grm. to −0·0072 grm.

In every case but one (5), the solution was neutral to litmus paper at the end of the period of electrolysis, which shows that in these determinations no hydrochloric acid remained as such. In each of two cases silver was found upon the platinum cathode to the amounts of 0·0011 grm. and 0·0015 grm. respectively, these amounts being determined by dissolving the metallic deposit in nitric acid, and weighing the silver chloride precipitated by hydrochloric acid from the solutions thus obtained. Plainly part of the apparent error in the fixation of chlorine is due in these cases to the transfer of silver from the anode to the cathode. Of the liquids tested, all but one became opalescent upon the addition of silver nitrate, as might be expected if hypochlorous acid or a hypochlorite, neither of which would turn blue litmus paper red,

TABLE I.—ELECTROLYSIS OF HYDROCHLORIC ACID WITH THE ANODE SILVER-PLATED IN A CYANIDE SOLUTION.

	Chlorine taken in HCl grm.	Time min.	Current		Increase of anode dried grm.	Increase of anode ignited grm.	Loss of dried anode on ignition grm.	Apparent error in chlorine when anode was dried grm.	Apparent error in chlorine when anode was ignited grm.	Remarks concerning residual liquid and cathode
			amp.	volt.						
					A.—Anode prepared by washing and gently igniting.					
(1)	0·1062	25	0·4–0·02	3–4	0·1043	0·0990	0·0053	—0·0019	—0·0072	Liquid neutral to litmus. $AgNO_3$ gave precipitate.
(2)	0·1062	30	0·4–0·02	3–4	0·1084	0·1036	0·0048	+0·0022	—0·0026	Liquid neutral to litmus. $AgNO_3$ gave precipitate.
(3)	0·1062	30	0·5–0·01	2·2–4	0·1070	0·1021	0·0049	+0·0008	—0·0041	Liquid neutral to litmus. $AgNO_3$ gave no precipitate.
(4)	0·1062	30	0·5–0·01	2–4	0·1066	0·1018	0·0048	+0·0004	—0·0044	Liquid neutral to litmus. Silver on cathode (0·0011 grm.). Residue left on evaporation weighed 0·0029 grm.
(5)	0·1062	40	0·5–0·01	3–4	0·1077	0·1007	0·0070	+0·0015	—0·0055	Liquid very faintly acidic to litmus. $AgNO_3$ gave precipitate.
(6)	0·1062	45	0·4–0·01	2–4	0·1051	0·1021	0·0030	—0·0011	—0·0041	Liquid neutral to litmus, and cloudy after 48 hrs. Silver on cathode weighed 0·0015 grm. Residue left by evaporation weighed 0·0035 grm.
					B.—Anode prepared by washing, boiling repeatedly, and gently igniting.					
(7)	0·1062	30	0·4–0·01	3–4	0·1078	0·1038	0·0040	+0·0016	—0·0024	Liquid neutral to litmus but faintly cloudy. Trace of silver on cathode. Residue after evaporation weighed 0·0024 grm., of which 0·0011 grm. was insoluble (AgCl) and 0·0013 grm. soluble.
(8)	0·1062	35	0·5–0·01	3–4	0·1120	0·1030	0·0090	+0·0058	—0·0032	Mercury cathode used. Liquid neutral to litmus. $AgNO_3$ gave precipitate in a small portion of the liquid. Residue on evaporation 0·0020 grm.

were contained in the solution. In one experiment (6) the solution, neutral to litmus, became spontaneously opalescent after standing forty-eight hours, as might very well be the case if the solution contained a trace of silver hypochlorite at the end of the electrolysis. These phenomena show that in the electrolytic analysis of hydrochloric acid with the silver-plated anode the process does not consist simply of the liberation of hydrogen at the cathode and the fixation of chlorine at the anode, but that these effects may be supplemented to a greater or less extent, according to the conditions, by the fixation of oxygen as well as chlorine, the production of oxygen compounds of chlorine, and the dissolving of silver from the anode with its more or less complete transfer to the cathode. Of silver in solution a trace was sometimes found by hydrogen sulphide but not enough to give a distinct test with hydrochloric acid, though in experiment (6) a trace of silver chloride was apparently thrown out spontaneously on standing.

In experiments (4) and (6) tests of the liquid with silver nitrate were omitted and the residues left on evaporation and heating were found to weigh 0·0029 and 0·0035 grm. respectively. Each residue was soluble in water and, after ignition, gave a test for chlorine with silver nitrate. Each contained no appreciable amount of silver, but did contain potassium; and, inasmuch as the acid taken left upon evaporation only an inconsiderable residue, the inference seemed plain that at least the greater part of the solid material must have been derived from salt included in the plating of the anode. Before proceeding further, therefore, this point was decided by carefully washing as usual a freshly plated anode, suspending it for some minutes in a beaker of water kept boiling, and then testing the water with silver nitrate, the production of cloudiness being taken as an indication of the presence of a soluble cyanide.

In Series B of the table are the results obtained in two experiments with the silver-plated anode carefully boiled out and gently ignited previous to its use in the electrolytic process. In experiment (8) mercury in a glass beaker and connected with the battery by a platinum wire sealed into glass to prevent contact with the liquid served as the cathode. In each of these experiments the neutrality of the residual liquids proved the absence of hydrochloric acid. In (7) a trace of silver was found upon the cathode, and the liquid became faintly cloudy toward the end of the electrolysis and left upon evaporation a residue of 0·0024, of which 0·0011 was insoluble in water and apparently silver chloride. In (8) a small portion of the liquid gave a precipitate with silver nitrate and the remainder left a residue of 0·0020 grm. These results confirm those of Series A and show errors of the same sort, though the soluble residue was considerably less. Apparently material included in the silver plating of the anode was not wholly extracted by the process of washing and boiling.

The next experiments were made with the rotating gauze anode plated with silver from a solution of silver oxalate in ammonium hydroxide to avoid all possible contamination of the silver deposit by nonvolatile material. The course of the electrolysis was similar to that of the experiments previously described, nearly to the finish; but, near the end, when neutrality to litmus indicated the exhaustion of hydrochloric acid, the solution suddenly became opalescent and soon afterward the current practically ceased to flow. Upon standing, the liquid, which at the end of the electrolysis had slowly bleached blue litmus paper without reddening it, developed distinct acidity, and when tested in separate portions gave further opalescence with silver nitrate and set free iodine from potassium iodide. All these phenomena point to the formation of hypochlorous acid in the process of electrolysis and its attack upon the anode to form silver hypochlorite and derived silver salts. It appears further, that in the absence of alkali salt, soluble silver hypochlorite, apparently formed chiefly when the hydrochloric acid approaches the point of exhaustion, is thrown into solution, to be partially decomposed with production of opalescent silver chloride. In Table II are given the details of experiments made with the silver anode plated in the oxalate solution. In the first experiment the electrolysis was continued until the current practically ceased to pass. In the other experiments the operation was ended when the diffusion of the opalescent silver chloride indicated that the silver anode was being attacked, dissolved, and partially reprecipitated in the liquid. In all the liquid was neutral at the end of the electrolysis.

The results of these experiments, in which no alkali salt derived from the plated anode could be present, confirm those of the preceding series in respect to the fixing of oxygen as well as chlorine upon the anode, the removal of silver from anode to cathode, and the formation of hypochlorous acid.

It is plain, therefore, that the electrolytic determination of the chlorine of hydrochloric acid with the use of the silver anode is by no means an exact process. Even when precautions are taken to plate the anode with a silver solution containing salts which, if included in the deposit, will leave nothing but silver, and to ignite the anode with the electrolytic deposit to the point of decomposition of attached silver oxide, the results are very irregular and always low.

Table II.

The Electrolysis of Hydrochloric Acid with a Silver Anode plated in the Oxalate Solution.

	Chlorine taken in HCl grm.	Time min.	Current		Increase of anode dried in air bath at 105°–110° grm.	Increase of anode ignited grm.	Loss of dried anode on ignition grm.	Apparent error in chlorine when anode was dried grm,	Apparent error in chlorine when anode was ignited grm.
			amp.	volt					
1*a*	0·0533	25	0·5–0·00	2–4	0·0513	0·0502	0·0011	—0·0020	—0·0031
2*b*	0·0533	30	0·45–0·01	2–4	0·0529	0·0520	0·0009	—0·0004	—0·0013
3*c*	0·0533	25	0·5–0·01	3–4	0·0513	0·0501	0·0012	—0·0020	—0·0032
4*d*	0·0533	30	0·5–0·01	3–4	0·0523	0·0517	0·0006	—0·0010	—0·0016
5*e*	0·0533	25	0·5–0·01	3·8–4	0·0517	0·0499	0·0018	—0·0016	—0·0034
6*f*	0·0533	25	0·4–0·03	3·8–4	0·0502	0·0493	0·0009	—0·0031	—0·0040
7*g*	0·0533	25	0·4–0·02	3·8–4	0·0506	0·0493	0·0013	—0·0027	—0·0040

a.—The solution became suddenly opalescent and soon thereafter the current practically ceased, the liquid being neutral to litmus paper. Silver chloride (0·0017 grm.) was recovered from the liquid, and silver was found upon the cathode.

b.—The electrolysis was interrupted at the first appearance of opalescence, the liquid being neutral. No silver was found in solution and none upon the cathode. Iodine, indicated by starch, was liberated when potassium iodide was added to a portion of the solution.

c.—At the end of the electrolysis the liquid was slightly opalescent and neutral to litmus. Upon the addition of potassium iodide to a portion of it a trace of iodine was set free. In another portion, silver nitrate was without immediate effect. A trace of silver was found upon the cathode.

d.—At the end of the electrolysis the liquid was slightly opalescent. It was neutral to litmus, but slowly bleached the color. Upon standing it developed acidity. From potassium iodide it liberated iodine equivalent to 0·0010 grm. of chlorine, as was determined by sodium thiosulphate. A trace of silver was found upon the cathode.

e.—At the end of the electrolysis the liquid was slightly opalescent. It was neutral to litmus but developed acidity in the course of a half-hour. From potassium iodine a portion set free iodine. In the remainder silver nitrate gave, after standing two days, an amount of silver chloride equivalent to 0·0016 grm. of chlorine. Silver was found upon the cathode.

f.—At the end of the electrolysis, the liquid was slightly opalescent. It was neutral to litmus, but developed acidity on standing a half-hour. From potassium iodide a small portion set free iodine. From the remainder silver nitrate precipitated silver chloride, which, when filtered off after five days, was found to be equivalent to 0·0035 grm. of chlorine. A trace of silver was found on the cathode.

g.—At the end of the electrolysis, the liquid was slightly opalescent. It was neutral to litmus, but developed acidity in a half-hour. A small portion of it set free iodine from potassium iodide. Silver nitrate produced in the remainder, after four days, a precipitate of silver chloride equivalent to 0·0036 grm. of chlorine. No silver was found upon the cathode.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Boiling-points of Metals.*—Our data in regard to the boiling-points of most of the common metals have been very uncertain and discordant, but H. C. Greenwood has recently made an extended investigation of this subject, and has succeeded in determining a number of these constants with a fair degree of approximation. He employed a slender graphite crucible placed in a slightly larger vertical carbon tube which was heated by electrical resistance. The temperature was measured by observation of the walls of the crucible through a horizontal tube connected with the carbon tube, by means of a Wanner optical pyrometer. The surface of the metal was observed through a window at the top of the apparatus, and its agitation indicated the boiling-point. A current of hydrogen was passed in at the side tube, as a protection to the crucible. It was found that the boiling-points were lower in the presence of a current of hydrogen than in the case where nitrogen was used, apparently on account of the fact that hydrogen easily penetrated the walls of the hot crucible and carried off or diluted the column of heavy vapor above the metal. In the cases of the metals which form carbides, the interior of the crucible was coated with magnesia in such a manner that practically no carbide was produced. When this precaution was not taken, boiling-points several hundred degrees too high were obtained in some cases. The following table gives the results as the approximate boiling-points of eleven metals:

Aluminium	1800° C.	Lead	1525° C.
Antimony	1440	Magnesium	1120
Bismuth	1420	Manganese	1900
Chromium	2200	Silver	1955
Copper	2310	Tin	2270
Iron	2450		

—*Chem. News*, c, 39, 49. H. L. W.

2. *Sodium Alum.*—This alum, $NaAl(SO_4)_2.12H_2O$, was made by several of the earlier investigators, but its existence has been questioned several times. For instance, Ostwald in his "Principles of Inorganic Chemistry" states that sodium and lithium do not form alums. W. R. Smith has now shown conclusively that the sodium alum may be easily prepared in well-developed crystals of the usual octahedral form, but he has shown also that it does not exist at temperatures much above 30° C. Above this temperature the separate salts crystallize side by side, and when the alum in contact with its saturated mother liquor is heated to the higher temperature it is decomposed into an opaque, finely divided mass. *Jour. Amer. Chem. Soc.*, xxxi, 245. H. L. W.

3. *The Elements of Metallography;* by Dr. Rudolf Rurer. Translated by C. H. Mathewson. 8vo, pp. 342. New York, 1909 (John Wiley & Sons).—Nearly the whole of this book is devoted to a very clear and full explanation of the recently developed methods for studying alloys. The theory of the fusion diagrams and the microscopic structure of these substances is discussed in an admirably simple and thorough manner. A comparatively short second part of the book deals with practical thermal and structural investigations. The translator has shown excellent skill in putting the work into English. The subject is of great importance both from practical and scientific points of view, and this book will doubtless afford much pleasure and profit to chemists and physicists, even though they may not be directly interested in the subject of alloys. H. L. W.

4. *Outlines of Chemistry with Practical Work;* by H. J. H. Fenton. 8vo, pp. 364. Cambridge, England, 1909, at the University Press (New York, G. P. Putnam's Sons).—This book has been prepared for use in connection with the author's course of instruction in general and physical chemistry at Cambridge University. It gives a somewhat condensed, but advanced, treatment of theoretical chemistry, with practical experiments for the student, usually at the end of each discussion of a lecture topic. It appears that the student is expected here to learn the theory and then, if possible, to study the facts which prove it. The book is interesting and it should prove useful to American teachers. The work does not cover the whole domain of chemical theory, but it is to be followed by a second volume.

H. L. W.

5. *An Elementary Treatise on Qualitative Chemical Analysis,* by J. F. Sellers. 12mo, pp. 176. Boston (Ginn & Company).

A Manual of Qualitative Chemical Analysis; by J. F. McGregory. 8vo, pp. 135. Boston (Ginn & Company).

These two text-books on qualitative analysis have just appeared in the form of revised editions, which is an indication that they have been extensively used. Both books follow practically the conventional course of analysis, and differ chiefly in the manner in which it is presented, and in the theorotical matter which is introduced. A considerable variety of text-books in qualitative analysis is required to meet the demands of teachers with courses of different character and length. H. L. W.

6. *The Periodic Law;* by A. E. Garrett. 12mo, pp. 294. New York, 1909 (D. Appleton & Company).—This book, which is one of "The International Scientific Series," gives a very full historical and theoretical discussion of the periodic classification of the elements. The subject is ably presented, and the book is supplied with many useful tables and diagrams. The subject is brought up to the most recent times, including, for instance, a discussion of Sir J. J. Thomson's views in regard to atomic structure. H. L. W.

7. *A Text-Book of Physical Chemistry, Theory and Practice;* by Arthur W. Ewell. 8vo, pp. 370. Philadelphia, 1909 (P. Blakiston's Son & Co.).—The author states that the book is intended to serve as a laboratory manual, as a text-book to accompany recitations or lectures and as a reference book. Much space is devoted to directions for a course of laboratory experiments, including the ordinary physico-chemical measurements and many which would not ordinarily be given in a students' course. These directions appear to be very good. The theoretical and descriptive part of the book is somewhat shorter and less complete than is perhaps desirable. The author assumes that the student has a knowledge of calculus. H. W. F.

8. *A Text-Book of Physiological Chemistry;* by John H. Long. Second edition, revised. 396 pp., with 42 illustrations. Philadelphia, 1909 (P. Blakiston's Son & Co.).—The second edition of Professor Long's book represents a thorough revision and extension of the earlier one. The book is intended primarily for use with laboratory classes, and is unusually well adapted to its purpose. The directions for the practical work are carefully presented, and serve to illustrate the more detailed discussion of the remainder of the text. This plan has, in the reviewer's opinion, distinct advantages over the arrangement of isolated directions found in the so-called manuals of chemistry. The physiological bearings are never allowed to vanish into the background; so that the functions of living things are continually being emphasized from the chemical point of view. The book is particularly adapted to the needs of medical students. L. B. M.

9. *Positive Rays.*—W. Wien continues his work of 1908 on this subject and concludes his investigation as follows:

(1) The positive rays of hydrogen at high vacua are less strongly influenced by magnetic fields than at low vacua.

(2) The rays which are weakened in a magnetic field are also weakened in respect to heat properties and light emission by a second magnetic field to approximately the same degree as those rays which have not been affected by the first magnetic field.

(3) The light emission is under otherwise equal conditions much less in high vacua than in low, and this is especially true of hydrogen as well as air.

(4) The magnetic influence does not depend to a large degree upon the potential difference exciting the tube.

(5) The canal rays of quicksilver do not convey a traceable positive discharge, and no deflection can be observed in strong magnetic fields by direct observation of the light emission.

The paper concludes with reflections upon the possibility of combination and recombination of ions and electrons, and on the possibility of light being emitted by positive ions in a neutral condition.—*Ann. der Physik*, No. 12, 1909, pp. 349–368. J. T.

10. *The apparent Fusion of Carbon in the Singing Arc and in Sparks.*—M. La Rosa gives a résumé of the work of Despretz and Moissan on the production of artificial diamonds, and con-

cluded to try the effect of a high tension spark on carbon dust which is suitably placed in a cavity of one of the electrodes. A current of 300 volts was employed: a side circuit included a condenser of 60 microfarad capacity with very small resistance and self induction. It was found that the temperature of the singing arc under the condition in which it gives the spark spectrum is much higher than that of the ordinary electric arc and the electric oven. The dust after the operation was carefully washed and treated in various solvents; finally crystalline forms were obtained of great hardness. The paper contains photographs of these forms, which in the main were made up of two tetrahedrons with curved surfaces. The author suspects that he has obtained diamonds, and hopes to determine this question by further investigation.—*Ann. der Physik*, No. 12, 1909, 369–380. J. T.

11. *Determination of* ϵ/m.—KURT WOLZ collects the various determinations of this ratio and uses Bucherer's method for a new determination. He obtains $\epsilon/m = 1{\cdot}7674 \times 10^7$, while Bucherer obtained $\epsilon/m = 1{\cdot}763 \times 10^7$.—*Ann. der Physik*, No. 12, 1909, pp. 273–288. J. T.

12. *Spectroscopie Astronomique*; by P. SALET. Pp. viii, 431, with 44 figures and 1 plate. Paris, 1909 (Octave Doin et Fils).—Under the direction of Dr. Toulouse the publication of a scientific encyclopedia comprising twenty-nine volumes is projected. As yet only two volumes have appeared, one of which has the author and title indicated above. The subject of astronomical spectroscopy is here presented from all points of view and in as interesting a manner as is consistent with the relatively small size (12°) of the pages. Although the text is somewhat synoptic nevertheless it is fully up to date and contains references to the latest discoveries as published in the scientific journals. At the end of each chapter a bibliographical list of the most important works relating to the topics discussed in the respective chapter is given. The book concludes with an alphabetical index of authors and of subjects together with a systematic table of contents. Unfortunately most of the figures of spectra are somewhat blurred and indistinct. However, on the whole, the volume affords excellent reading matter introductory to a more detailed study of astronomical spectroscopy. H. S. U.

13. *A Text-Book of Physics, Second Edition*; edited by A. W. DUFF. Pp. xi, 698, with 525 figures and 245 problems. Philadelphia, 1909 (P. Blakiston's Son & Co.).—The revised edition of this work (see vol. xxvii, page 85) differs from the first in the following respects. The chapter on wave motion, which was formerly composed by W. Hallock, has been entirely rewritten by E. P. Lewis. Many of the articles have been changed from large to small type and vice versa. As a result the large print portions of the book now constitute a well-balanced briefer course. A number of the poorer figures have been replaced by much better diagrams. Certain articles now conclude with illustrative tables of physical constants. At the end of each general

subdivision of physics a list of well-selected reference books is given. Also brief comments on the characteristics of these books are made. Finally, the problems at the end of each complete chapter have been classified with heavy type, marginal titles and numerical answers are appended. On the whole, the book has been greatly improved by the process of revision so that it is now a thoroughly reliable text. H. S. U.

14. *General Physics: Mechanics and Heat;* by J. A. Culler. Pp. ix, 311, with 225 figures. Philadelphia, 1909 (J. B. Lippincott Co.).—This book is designed for the use of college students who possess a working knowledge of plane trigonometry. Proofs of various formulæ which involve the integral calculus are given in the appendix. This portion of the book also contains tables of physical constants, of natural trigonometric functions, and of common logarithms. In the prefatory note, the author says: "The aim of the writer has constantly been to say the words that would help the student to understand the subject." In this endeavor as well as in the matter of accuracy of statement he has often failed. Two typical quotations will suffice to justify this adverse criticism.

On page 69 the following statements are made. "The centre of gravity and *centre of mass* coincide, but their definitions are different." "The centre of mass is a point whose distance from the three planes of reference is equal to the mean distance of the particles, supposed equal, from the same planes."

On page 39 Newton's laws of motion are stated in the following new and incorrect forms.

"(1) Every body of matter persists in its state of rest or motion.

"(2) The effect of an impulse in changing the momentum of a mass of matter is independent of other impulses which may be applied at the same time and of the momentum which the mass may already have.

"(3) The application of a force is always accompanied by an equal resistance in the opposite direction, and the energy expended by any body acting as agent is equal to the energy received by another body which resists the agent." H. S. U.

II. Geology.

1. *Publications of the United States Geological Survey,* George Otis Smith, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from p. 80):

Topographic Atlas.—Thirty-eight sheets.

Folios—No. 166. El Paso Folio, Texas. Description of the El Paso District; by G. B. Richardson. Pp. 11; 2 maps, 15 figures.

No. 168. Jamestown-Tower Folio, North Dakota. Jamestown, Eckelson, and Tower Quadrangles. Description of Jamestown-Tower District; by DANIEL E. WILLARD. Pp. 10; 9 maps, 6 figures.

PROFESSIONAL PAPERS.—No. 64. The Yakutat Bay Region, Alaska. Physiography and Glacial Geology; by RALPH S. TARR. Areal Geology by RALPH S. TARR and BERT S. BUTLER. Pp. 183; 37 plates, 10 figures.

No. 66. The Geology and Ore Deposits of Goldfield, Nevada; by FREDERICK LESLIE RANSOME, assisted in the field by W. H. EMMONS and G. H. GARREY. Pp. 258, 34 figures.

No. 67. Landslides in the San Juan Mountains, Colorado, including a consideration of their causes and their classification; by ERNEST HOWE. Pp. 58; 20 plates, 4 figures.

BULLETINS.—No. 341. Contributions to Economic Geology, 1907. Part II. Coal and Lignite. MARIUS R. CAMPBELL, Geologist in charge. Pp. 444; 25 plates, 7 figures.

No. 385. Briquetting Tests at the United States Fuel-Testing Plant, Norfolk, Virginia, 1907–8; by CHARLES L. WRIGHT. Pp. 41; 9 plates.

No. 389. The Manzano Group of the Rio Grande Valley, New Mexico; by WILLIS T. LEE and GEORGE H. GIRTY. Pp. 141; 12 plates, 9 figures.

No. 391. The Devonian Fauna of the Ouray Limestone; by E. M. KINDLE. Pp. 60; 10 plates.

No. 392. Commercial Deductions from Comparisons of Gasoline and Alcohol Tests on Internal-Combustion Engines; by ROBERT M. STRONG. Pp. 37.

No. 393. Incidental Problems in Gas-Producer Tests; by R. H. FERNALD, C. D. SMITH, J. K. CLEMENT and H. A. GRINE. Pp. 27; 8 figures.

No. 395. Radioactivity of the Thermal Waters of Yellowstone National Park; by HERMAN SCHLUNDT and RICHARD B. MOORE. Pp. 35; 4 plates, 7 figures.

No. 399. Results of Spirit Leveling in West Virginia 1896 to 1908, inclusive. Compiled by S. S. GANNETT and D. H. BALDWIN. In coöperation with the West Virginia State Geological Survey during 1901 to 1908, inclusive. Pp. 81.

No. 401. Relations between Local Magnetic Disturbances and the Genesis of Petroleum; by GEORGE F. BECKER. Pp. 24; 1 plate. See p. 499.

No. 402. The Utilization of Fuel in Locomotive Practice; by W. F. M. GOSS. Pp. 27, 8 figures.

No. 403. Comparative Tests of Run-of-Mine and Briquetted Coal on the Torpedo Boat Biddle. Made, with the collaboration of Lieut. Commander Kenneth McAlpine, U. S. N., and Ensign J. W. Hayward, U. S. N.; by WALTER T. RAY and HENRY KREISINGER. Pp. 48; 10 figures.

WATER-SUPPLY PAPERS.—No. 224. Some Desert Watering Places in Southeastern California and Southwestern Nevada; by WALTER C. MENDENHALL. Pp. 98; 4 plates.

No. 227. Geology and Underground Waters of South Dakota; by N. H. DARTON. Pp. 156; 15 plates, 7 figures.

No. 232. Underground Water Resources of Connecticut; by **Herbert E. Gregory.** With a Study of the Occurrence of Water in Crystalline Rocks; by **E. E. Ellis.** Pp. 200; 5 plates, 31 figures.

No. 235. The Purification of some Textile and other Factory Wastes; by **Herman Stabler** and **Gilbert H. Pratt.** Prepared in coöperation with Rhode Island State Board of Health. Pp. 76.

No. 242. Surface Water Supply of the United States, 1907–8. Part II. South Atlantic Coast and Eastern Gulf of Mexico. Prepared under the direction of **M. O. Leighton**, by **M. R. Hall** and **R. H. Bolster.** Pp. 226; 3 plates, 1 figure.

2. *Indiana—Department of Geology and Natural Resources. Thirty-Third Annual Report.* **W. S. Blatchley**, State Geologist, 1908. Pp. 663, 4 plates, 1 figure. Indianapolis, 1909 (Wm. B. Burford).—The most extensive chapter in this volume is devoted to the coal deposits, and is supplementary to the report on the same subject issued in 1898; it is accompanied by a large map. It is stated that a conservative estimate puts the amount of coal in the state at 50 billion tons, of which 14 billion are regarded as workable under present conditions. In 1907, 13,250,000 tons were mined, and the rate has increased at about one million tons per year. Other chapters deal with soil surveys in several counties, the petroleum industry and that of the natural gas, now nearly exhausted. Strictly scientific papers are given by E. M. Kindle and V. H. Barnett on the Waldron fauna of Southern Indiana, and by W. L. Hahn on the mammals of the state.

3. *Colorado Geological Survey;* **R. D. George**, State Geologist. First Report, 1908. 229 pp., 4 maps, 22 pls.—Colorado has had a state geologist since 1872; an official, however, who has had no funds at his disposal to carry on the work. The state legislature of 1907 established the State Geological Survey with an appropriation which, though small, has already resulted in accomplishing important work. The newly appointed State Geologist, with the coöperation of Professor Patton and a geological staff of fifteen men, has completed a report on the "Main Tungsten Area of Boulder County," the "Montezuma Mining District of Summit County," the "Foothills Formation of Northern Colorado," and the "Hahn's Peak Region, Routt County." A topographical map of the state has been compiled and will soon be issued; the Survey is engaged in compiling a geological map of the state which will present the results of all the work done up to the present time. The plans as outlined for the future indicate an intelligent appreciation of the needs of the state and of the opportunity for investigation of important geological problems. H. E. G.

4. *Geological Survey of Michigan.*—The Ninth Annual Report of the State Geologist, **Alfred C. Lane**, for the year 1907 has recently been issued. Also, as part of the same, the following:

Foundry Sands; by HEINRICH RIES and J. A. ROSEN. Pp. 41–85; with 3 figures, 5 plates.

Summary of the Surface Geology of Michigan; by ALFRED C. LANE. Pp. 93–143; figures 4–17, 7 plates.

A Biological Survey of Walnut Lake, Michigan; by THOMAS L. HANKINSON. With chapters on the Physiography, Geology and Flora of the Region, by CHARLES A. DAVIS; and a paper on the Aquatic Insects of the Lake, by JAMES G. NEEDHAM. Pp. 155–288. 63 plates, 6 figures.

5. *Illinois Geological State Survey.* H. FOSTER BAINS, Director.—The Illinois Survey has recently issued Bulletin No. 10 on the Mineral Content of Illinois Waters. This has been prepared, in coöperation with the State Water Survey, by EDWARD BARTOW, J. A. UDDEN, S. W. PARR and GEORGE T. PALMER. It gives an account of the Illinois waters, with analyses from many localities.

Circular No. 5, on the Mineral Production of Illinois in 1908, by R. S. BLATCHLEY, gives the statistics for 1908. It shows that the coal production in Illinois for 1908 was 47,600,000 tons, a decrease of 7 per cent from 1907. The iron production also fell off largely, but in oil there has been a remarkable increase since 1904, when there was no record of oil in commercial quantities. Rapid development began in 1906, and in 1908 the production amounted to nearly 34,000,000 barrels; this gives Illinois the third place among the states of the Union.

6. *History, Geology and Statistics of the Oklahoma Oil and Gas Fields;* by E. R. PERRY and L. L. HUTCHISON.—This brief pamphlet is issued in order to show the present development of the industries named; a formal report to the Geological Survey is in process of preparation. Although the youngest state in the Union, the oil fields of Oklahoma produced, in 1908, nearly 46,000,000 barrels of crude petroleum, more than any of the other states. California comes second, and Illinois, Texas and Ohio follow, while Pennsylvania is seventh in the list.

7. *Les Variations Periodiques des Glaciers, XIII Rapport, 1907;* par DR. ED. BRUCKNER et E. MURET. Zeitschrift fur Gletscherkunde, vol. iii, 1909.—An examination of glaciers during 1907 shows the following results: In the Central Alps, one glacier, the Vorab in the Rhine Basin, is increasing; twelve are marked as possibly increasing; one is stationary; four are probably decreasing, and fifty certainly decreasing. In the Eastern Alps, one glacier is probably advancing; one is stationary; twenty-four are in retreat; while the glaciers of the Italian Alps, of Savoie and Dauphiné, with one exception show retreat. The only glacier measured in the Pyrenees was found to be stationary. In Norway, the glaciers of Jotunheim show a distinct tendency to elongation. In 1904-05, six were advancing, four were retreating; 1905-06, seven were advancing, seven were retreating; during the years 1906-07, fifteen were advancing and only three retreating.

In the Caucasus, Karagom and Bartui are retreating, while Midagrawin of the Kasbek group is apparently advancing. In the Pamir, a group of recently explored glaciers show evidences of retreating, and the Himalaya glaciers show a general retreat coupled with sudden spasmodic advance on the part of certain smaller ice lobes. In North America, the Hallett glacier (Colorado) and several of the glaciers on Mount Hood seem to be advancing. Those of British Columbia are receding and the Alaska glaciers appear to be retreating, those in the Muir and Reid inlets being modified by the earthquake of 1909. H. E. G.

8. *Hand Book for Field Geologists;* by C. W. HAYES, Chief Geologist, Geological Survey. Second edition, thoroughly revised First thousand. Pp. viii, 159 ; 18 figures. New York 1909 (J. Wiley & Sons).—This treatise is divided into two parts, the first dealing with the equipment, instruments and methods of observation and collection; the second part giving instructions for special field investigations in petrology, structural geology, economic geology, etc. The value of the book is vouched for by its contents and by the name of the author. It should be in the hands of all young students of geology, and will be found of assistance to field workers of large experience. H. E. G.

9. *A critical summary of Troost's unpublished manuscript on the crinoids of Tennessee;* by ELVIRA WOOD. Bull. 64, U. S. Nat. Mus., 1909, pages vii and 1–150, plates 1-15.—In 1849 Louis Agassiz presented before the American Association for the Advancement of Science a short paper by Gerhard Troost, then State Geologist of Tennessee, on the fossil crinoids of that state. "Troost's list," numbering 85 species, was published in the Proceedings of the above society, but very little otherwise has been made known of his studies until now, when the National Museum does justice as best it can to the distinguished pioneer in American geology and paleontology.

The manuscript written in 1849 and submitted the following year to the Smithsonian Institution described 108 species. Miss Wood here treats 100 forms divided among the cystoids (7), blastoids (7), crinoids (84), starfishes (1) and echinoids (1). Even at this late date 39 specific names proposed by Troost will stand, the remainder having been described by others since 1849. Of genera, Troost proposed 16, of which 4 stand. Miss Wood proposes 4 new species or new names, and adds many excellent wash drawings and retouched photographs of her own making. The author has put a great deal of hard work on the Troost manuscript to bring it up to date. We are grateful for this labor of love, and congratulate her on the excellence of her studies. C. S.

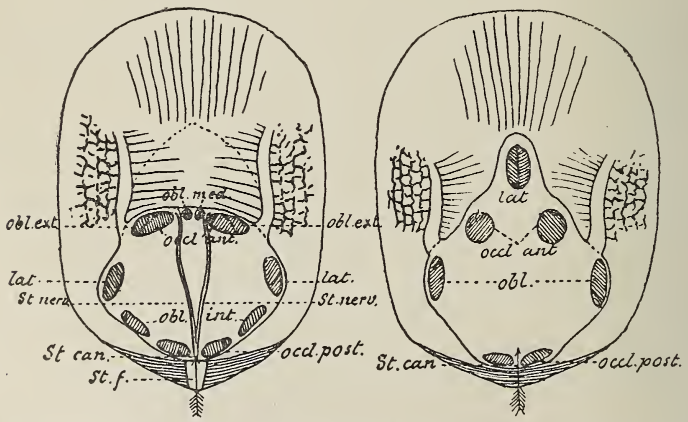
10. *Dendroid Graptolites of the Niagaran dolomites at Hamilton, Ontario;* compiled by RAY S. BASSLER, Bull. 65, U. S. Nat. Mus., 1909, pp. 76, plates 5.—Hamilton, Ontario, has long been famous for its abundance of dendroid graptolites and they may be found in many museums, due chiefly to Colonel Charles Coote Grant. There are now known from this locality the surprising

number of 52 forms, and it was R. R. Gurley's intention to monograph these graptolites. The work was left uncompleted and is now put in good order by Bassler. The geologic horizon appears to be the lower portion of the Lockport dolomite. But five of the species are found in lower horizons, four in the Rochester shale (*Dictyonema retiforme*, *D. polymorphum*, *Inocaulis plumulosus*, *Acanthograptus walkeri*) and one in the Upper Clinton (*Cyclograptus rotadentatus*). C. S.

11. *A Carboniferous fauna from Nowaja Semlja, collected by Dr. W. S. Bruce;* by G. W. LEE. Trans. Royal Soc. of Edinburgh, 47, 1909, pp. 143-186, pls. 1, 2.—From a bed of limestone (Cape Cherney) on the west coast of southern Nova Zembla, in lat. 70° 49′ and long. 56° 37′ was collected a most interesting fauna of over 90 species. These are of the Productus giganteus horizon, here rich in brachiopods, foraminifers (7 species), corals and mollusca (dwarfed forms). No cephalopods are present. The fauna is "very closely allied to that of the Giganteus zone of the Urals and Central Russia, which is practically the same as that of Western Europe." Carruthers studied the corals and in regard to the horizon states that it is "between the base of the Upper Carboniferous and the top of the Lower Carboniferous of the Russian classification." C. S.

12. *Vorläufige Mitteilung über das genus Pseudolingula;* von A. MICKWITZ. Bull. l'Acad, Imp. Sci. St. Petersbourg, 1909; pp. 765–772.—The author shows that *Lingula quadrata*, occurring at the top of the Estlandian Ordovician, has a pedicle groove and a pair of umbonal muscles instead of a single muscle and no groove

FIG. 1. FIG. 2.



FIGURES: 1, 2, schematic drawing of the internal characters of *L. quadrata*. After Mickwitz. 1 ventral, 2 dorsal views: *occl. ant.*, *post.*=occlusor anterior, posterior; *obl. int.*, *ext.*, *med.*=obliquus internus, externus, medius; *lat.*=lateralis; *st.*=pedicle; *st. can.*=pedicle canal; *st. f.*=pedicle groove; *st. nerv.*=pedicle nerve.

as in Lingula. Pseudolingula (new) is therefore still closely related to Obolus in its pedicle characters. He also thinks the same features are present in *L. lesueuri* and *L. rounaulti* of the Silurian.

The reviewer has looked over his collection of Lingulas and thinks that the characters of Pseudolingula may also be present in *L. cincinnatiensis*, *L. iowensis* and *L. lewissi.* The preservation, however, is not good enough to determine conclusively the point in question. C. S.

13. *History of the Clay-Working Industry in the United States;* by HEINRICH RIES and HENRY LEIGHTON. First edition. First thousand. Pp. viii, 270; 8 plates, 3 figures. New York, 1909 (J. Wiley & Sons).—The senior editor of this volume published, some years since, a work on the occurrence and use of clays in the United States (see vol. xxiii, p. 71). The present work is more comprehensive and historical and gives an account of the way in which this industry, one of the earliest to be developed in this country, has grown to its present magnitude. It may not be appreciated that the value of clay products in 1906 attained the total—a maximum thus far—of $161,000,000. Among the different states Ohio has for many years occupied the first place with $30,000,000 of products, and Pennsylvania the second with $20,000,000; New Jersey, Illinois and New York come next in order. This work will be found to contain many interesting facts by those concerned with the subject with which it deals.

14. *Elements of Mineralogy, Crystallography and Blowpipe Analysis from a practical standpoint:* by ALFRED J. MOSES and CHARLES LATHROP PARSONS. Fourth edition, pp. 448, with 583 figures. New York, 1909 (D. Van Nostrand Company).—This useful work, first issued in 1895, has now reached its fourth edition, with numerous additions and improvements. Some new details have been added, and the statistics of production, which form a valuable feature, have been brought up to date.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The autumn meeting of the National Academy was held at Princeton, N. J., on Nov. 16–18. The meeting was largely attended and the hospitality of the university authorities made the occasion a memorable one. The sessions were held in the new Arnold Guyot Hall and in part also in the Palmer Physical Laboratory. In the latter place a lecture was delivered on Tuesday afternoon by Professor W. F. Magie on the Investigations of Joseph Henry illustrated by Professor Henry's own apparatus. There was also an exhibition on Wednesday illustrating recent scientific investigations in the Museum of Guyot Hall. The titles of papers presented for reading are given in the following list:

A. AGASSIZ: On the presence of teeth in *Echinonëus* Van Phels.

W. B. SCOTT: The geology of South Africa.

E. G. CONKLIN: Formative substances in eggs. The relative sizes of cells and nuclei. Memoir of W. K. Brooks.

T. H. MORGAN : A study of immunity to self-fertilization in *Ciona.*

D. M. BARRINGER : Meteor Crater, Arizona.

E. F. SMITH : Derivatives of tantalum. Some new methods in electro-analysis.

O. W. RICHARDSON : The emission of electricity by hot bodies.

W. M. DAVIS : The physiography of southeastern Alaska.

E. HUNTINGTON : The Yale expedition of 1909 to Palestine and Syria.

E. S. MORSE : The early stages of *Acmæa.*

S. FLEXNER : The transmission of epidemic poliomyelitis to monkeys.

A. G. WEBSTER : The present status of the ether.

E. B. FROST : Examples of recent photographs made at the Yerkes Observatory. Memoir of C. A. Young.

C. D. WALCOTT : The development of *Olenellus.*

H. F. OSBORN : Report of investigations on the correlation of Tertiary and Quaternary horizons in Europe and North America. The skull of *Tyrannosaurus.*

H. N. RUSSELL : The fission of double stars.

S. PATON : The first movements of the vertebrate embryo in relation to the development of the nervous system.

U. DAHLGREN : The development of electric tissue in teleost fishes.

F. W. CLARKE : Memoir of Wolcott Gibbs.

2. *Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are given in the following list (continued from vol. xxvii, p. 367):

No. 85. Index of Economic Material in Documents of the States of the United States. Illinois, 1809–1904. Prepared for the Department of Economics and Sociology of the Carnegie Institution of Washington ; by ADELAIDE R. HASSE. Pp. 393.

No. 104. Cave Vertebrates of America. A Study in Degenerative Evolution ; by CARL H. EIGENMANN. Pp. v, 241 ; 29 plates.

No. 107. Contributions to Cosmogony and the Fundamental Problems of Geology. The Tidal and other Problems ; by T. C. CHAMBERLIN, F. R. MOULTON, C. S. SLICHTER, W. D. MACMILLAN, ARTHUR C. LUNN and JULIUS STIEGLITZ. Pp. iv, 264. Noticed on p. 188 of this volume.

No. 110. The Absorption Spectra of Solutions of Certain Salts of Cobalt, Nickel, Copper, Iron, Chromium, Neodymium, Proscodymium, and Erbium in Water, Methyl, Alcohol, Ethyl Alcohol, and Acetone, and in Mixtures of Water with the other Solvents ; by HARRY C. JONES and JOHN A. ANDERSON. Pp. vi, 110 ; 81 plates. Noticed on p. 78.

No. 111. Snake Venoms. An Investigation of venomous Snakes with special reference to the phenomena of their venoms; by HIDEYO NOGUCHI. Pp. xvii, 315 ; 33 plates.

No. 112. Bursa Bursa-Pastoris and Bursa Heegeri Biotypes and Hybrids ; by GEORGE HARRISON SHULL. Pp. 57 ; 23 figures and 4 plates.

No. 113. Distribution and Movements of Desert Plants ; by VOLNEY M. SPALDING. Pp. v, 144 ; 31 plates.

No. 114. Studies of Inheritance in Rabbits ; by W. E. CASTLE, in collaboration with H. E. WALTER, R. C. MULLENIX, and S. COBB. Pp. 70, 4 plates.

No. 117. Studies in Heredity as illustrated by the Trichomes of Species and Hybrids of Juglans, Oenothera, Papaver, and Solanum; by WILLIAM AUSTIN CANNON. Pp. iii, 67; 10 plates, 20 figures.

No. 118. Electrochemical Investigation of Liquid Amalgams of Thallium, Iridium, Tin, Zinc, Cadmium, Lead, Copper, and Lithium; by THEODORE WILLIAM RICHARDS, with the collaboration of J. HUNT WILSON and R. N. GARROD–THOMAS. Pp. 72; 12 figures.

3. *Harvard College Observatory;* EDWARD C. PICKERING, Director.—Recent publications are the following (continued from vol. xxvii, p. 420):

ANNALS. Vol. LXIV, No. IV. Discussion of the Revised Harvard Photometry. Pp. 91–146.

No. V. Observations on J. D. 3182 with the 4-inch Meridian Photometer. Pp. 147–158.

No. VI. Magnitudes of Components of Double Stars. Pp. 159–189.

4. *Allegheny Observatory of the University of Pittsburgh.*—Recent publications are the following (see vol. xxvii, p. 420):

Vol. I, No. 15. The Orbit of π^4 Orionis; by ROBERT H. BAKER. Pp. 107–111.

No. 16. The Radial Velocities of Four Stars in Taurus; by FRANK C. JORDAN. Pp. 113–4.

No. 17. The Orbit of ζ^1 Lyræ; by FRANK C. JORDAN. Pp. 115–118.

No. 18. The Longitude and the Latitude of the New Allegheny Observatory; by FRANK SCHLESINGER. Pp. 119–20.

No. 19. Five New Spectroscopic Binaries; by FRANK SCHLESINGER. Pp. 121–22.

5. *Museum of the Brooklyn Institute of Arts and Sciences.*—The following have recently appeared: Science Bulletin, Vol. I, No. 16.—New Birds from the Orinoco Region and from Trinidad; by GEORGE K. CHERRIE. Pp. 387–390.

6. *The Story of the Comets simply told for general readers;* by GEORGE F. CHAMBERS. Pp. xiii, 256; 106 figures. Oxford, 1909 (Clarendon Press).—A popular treatise based on the chapters on comets in the author's well-known Handbook of Astronomy, much enlarged and embodying the latest facts and theories. The work is characterized by the same merits as the other popular treatises of this author, and it is so abundant in details and so well classified as to form a useful book of reference for the working library of an astronomer. W. B.

7. *Mars et ses Canaux. Les Conditions de Vie.* Traduit de l'Anglais par MARCEL MOYEN. Pp. 366 with 64 figures. Paris, 1909 (Mercreve de France).—Whatever may be thought of the work of Percival Lowell, whether the phenomena on the surface of Mars which he describes are facts or the product of auto-suggestion, there is no difference of opinion as to his sincerity, his singleness of purpose and his keenness of vision and fertility of invention; so that his laborious researches deserve the wide-

spread interest which his attractive presentation of them excites. Professor Moyen's excellent translation will bring the subject at first hand to a large number of intelligent critics, most of whom will probably feel half persuaded that Mars is inhabited by intelligent beings. W. B.

8. *Manual for Engineers;* compiled by CHAS. E. FERRIS. Published by University of Tennessee, Knoxville. Pp. 246.—The tables in this little volume contain valuable statistics in a wide range of subjects, from pure mathematics to engineering and various matters connected with business. In addition to the obvious useful features of such a work its compilation has been carried out with a view to influence leading men in the south and to show the value of a technical education as a means of developing the natural resources.

9. *Wood Turning. Prepared for the use of students in Manual Training High Schools, Technical Schools and Colleges;* by GEORGE ALEXANDER ROSS. Pp. 76; 93 figures, 6 plates. Boston, 1909 (Ginn & Co.).—This is a practical work on the subject of wood-turning, with instructions concisely and clearly stated, and numerous excellent illustrations.

10. *Sir Joseph Banks: "The Father of Australia";* by J. H. MAIDEN, Government Botanist of New South Wales. Pp. xiv, 244. 64 illustrations. 1909. Sydney (W. A. Gullick) and London (Kegan Paul, Trench, Trübner & Co.).—This is an interesting account of an Englishman whose work for geographical exploration and science has had a wide influence on the development of his country. He was born in London in 1743 and died in 1820. He is known chiefly as a traveler, in addition to other notable voyages, having accompanied Capt. Cook on his first voyage in 1768–71, when New South Wales was discovered. His part in connection with this discovery, and also as a patron of early Australian exploration and colonization, have won him the title of "The Father of Australia." He was actively interested in science, and his botanical collections formed the foundation of the General Herbarium of the British Museum; his name has been given to a number of well-known species. He was also a patron of the arts and in other ways gave the world the benefit of his rare energy, ability and high character.

11. *American Association for the Advancement of Science.*—The sixty-first meeting of the American Association will be held in Boston during the week beginning December 27, under the presidency of President David Starr Jordan. This is the regular convocation-week meeting—the eighth of the series—when the sessions of the Association take place simultaneously with those of a large number of affiliated societies. A preliminary circular has already been issued by the Permanent Secretary, Dr. L. O. Howard, of the Smithsonian Institution, Washington, from whom further information may be obtained.

It is expected that the Association will visit the Hawaiian Islands in the summer of 1910 and hold the following convocation-week meeting in the twin cities of Minneapolis and St. Paul.

INDEX TO VOLUME XXVIII.*

* This Index contains the general heads. Botany, Chemistry (incl. chem. physics), Geology, Minerals, Obituary, Rocks, Zoölogy, and under each the titles of Articles referring thereto are mentioned.

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